ENGINEERING

An Illustrated Weekly Journal

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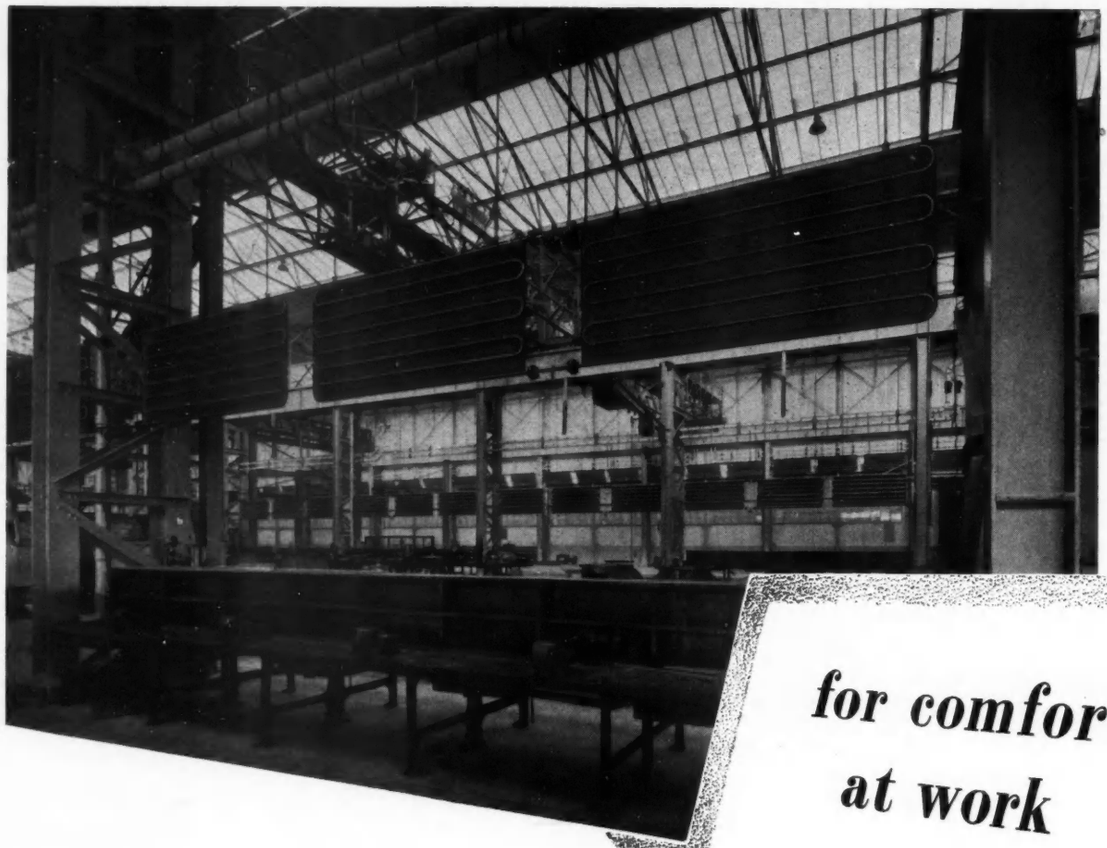
ENGINEERING

ASSEMBLING A STEAM-TURBINE ROTOR



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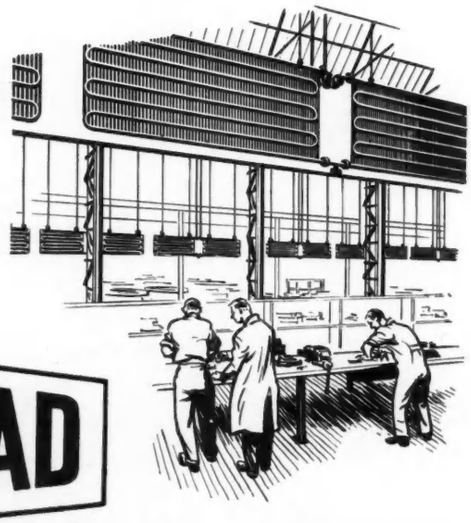

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CARROTS OR CO-OPERATION ?

It is a surprising fact that incentive payment schemes are more prevalent in British industry than in the United States. It has become almost an axiom of the productivity pundits in this country that bonus or piecework payments are essential for high output, and a high proportion of engineering workers are so paid. Some doubts on the efficacy of such systems, at any rate when introduced without substantial management changes, were cast by Dr. F. A. Wells in the paper on " Productivity in the Firms " which he presented at the British Association meeting.

Difficult as it is to measure differences in productivity, or output per man-hour, between firm and firm or between different periods in the same firm, it is still more difficult to analyse the factors which account for these differences. It is to this problem that Dr. Wells, of Nottingham University, has been devoting his inquiries in a particular firm in an unnamed industry in which the labour costs as a percentage of total costs had risen from 25·5 per cent. before the war to 40·8 per cent. in the period 1946 to 1952. This rise was not due to higher wages, but to a decline in labour productivity, and, as part of an all-round effort to reverse this trend, a bonus scheme already in operation in one small department was extended to a bigger one. The scheme was introduced by outside specialists, after full consultation and agreement with the workers, and output was increased by one-third in the first section and by nearly two-thirds in the second and bigger section. The increase in earnings averaged 10*d.* an hour for skilled men and 7*d.* an hour for semi-skilled women, but there were wide differences in bonus earned, not only between workers but also between the highest and lowest hourly bonus earnings of individual workers. The latter was due to failure to achieve uniformity in the pricing of jobs for, in spite of all the care devoted to job analysis and time study, there were still good and bad jobs.

The increased output was not due to any spectacular increase of working speed, although time-keeping improved. It was the indirect effects which were more important. Workers were now quick to complain if kept waiting for materials or new jobs or for machine adjustments; so that the incentive scheme produced its results largely through its effects on management. There were repercussions throughout the firm's organisation. The sales department was put on its toes to find outlets for the increased production, to pay due regard to the planning of production and to ensure that there were no changes once work was in progress. The methods of the works order office had to be improved. Preparatory work previously done by machine operatives was transferred to a special section.

In spite of these changes and the increased output that resulted therefrom, the actual saving in costs was less than expected. Against the additional recovery of overheads there had to be set the cost of the increased earnings of the workers, the cost of staff required to operate the scheme and a proportion of the cost of installing the scheme treated as a capital investment, and these together halved the potential saving. There were also wide discrepancies between estimated labour costs based on productive standard minutes and actual costs. This was due partly to technical causes and partly to the difficulty of securing the co-operation of operatives in working to standard methods.

The main conclusion of this study is not new: wage incentives are no substitute for good management. In fact they increase the responsibilities of management at all levels, and particularly at the departmental level. It may be that improved methods of working can be more economically introduced in some cases by work study, improved supervision and higher time rates of wages. It is not enough, however, to instal new methods of management. Just as new mechanical equipment may require workers to be trained in its use and may arouse a certain amount of Luddite opposition, so may new management techniques, such as cost control and management accounting. Without the full interest and understanding of managers at all levels the potential value of such techniques is never realised.

A depressing finding of this report was the lack of interest in productivity among the workers, although it was a happy firm. There were signs that this was due to a feeling that the goodwill that existed for the firm was seldom drawn upon, in spite of the existence of a joint advisory committee. On the other hand, the committee set up to operate the incentive scheme was working well and for this there appeared to be two reasons. One was that it was based on the trade union organisation within the firm, and the other that it gave the union members and officials opportunity for joint consultation on subjects that really mattered and in a form which could be effective.

The findings of this interesting inquiry, which are supported by those of other research workers, need to be confirmed by work in other firms and other industries; but they are worth serious consideration by managements and unions everywhere.

Weekly Survey

Cover Picture: *The illustration this week shows the wheel of an intermediate-pressure rotor for a 75 MW steam turbine being fitted on to the shaft. The wheels are forged steel discs, the rims of which are grooved to carry the blades. Before being mounted they are frequently run at an overspeed to test them. The wheel is first heated and is then lowered over a key which is already in position (though not visible in the illustration). When the wheel cools the necessary shrink fit is produced between it and the shaft.*

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PRICES AND WAGES

The British Employers' Confederation has never been associated with frequent pronouncements about its intentions or its view on public affairs. When it speaks, therefore, there is all the more reason to listen to its opinions: vows of silence are not broken without reason. In a plan called "Britain's Industrial Future" published last week the Confederation puts out a challenge to Government, the employers and workers, to accept their full responsibility as contributory factors to the present dangerously inflationary position. The Director of the Confederation, Mr. George Pollock, said last week that the Confederation and the Trades Union Congress must get together and examine the situation. The Confederation for their part were quite prepared to discuss dividends and wages with the T.U.C.—a remark which was particularly timely in view of the opinions expressed the week before at the T.U.C's annual conference at Southport, when the plea was put forward by trade unionists for prices to be restrained in order to preserve the purchasing power of wages.

The document goes on to deal with inflation and the problem of prices and the wages spiral. Government expenditure on the welfare state and food subsidies are blamed as contributing to inflation, and heavy Government capital expenditure is also criticised. A call is made for the exploration of shift working in the hope that it might be increased to ensure the maximum use of capital equipment in factories and on the land. The plan says that both employers and workers should recognise that in the long run everybody's interests would be best served by a reduction in prices.

The fact that the Confederation has spoken and the timing of its pronouncement are much more important at this stage than the content. There is a good deal in its analysis of the present economic situation which will not be to the liking of the T.U.C., notably its strong condemnation of food subsidies. If, however, when this document is laid before the next meeting of the Joint Consultative Committee (which includes representatives of the Government, the employers, the nationalised industries and the T.U.C.) all taking part realising that the two sides of industry have publicly agreed on the end to be achieved, a mutual spirit of accommodation and understanding may develop as to the means which might be employed to attain it.

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OUTLOOK FOR TIMBER

A recent assessment by the Economic Commission for Europe and the Food and Agricultural Organisation concludes that there should be no sudden change in the European timber market for the rest of this year. Although deliveries have been slowed down this summer, owing to the dock and railway strikes in the United Kingdom and the ships' officers' strike in Sweden, normal delivery plans for this year are not expected to be hampered to any extent. Higher wages in the main producing and exporting countries may raise the price of delivered roundwood, but it is not clear how far these will affect the export prices of manufactured forest products. The report emphasises the reluctance of the industry to upset the present stable level of prices.

It is expected that the turnover in the international sawn softwood market will be a record this year. The demand for forest products, especially pulp and paper, was good in the first half of the year but there may be a slight softening of the market so far as sawn softwood is concerned. The report foresees that heavy buying by importers may result in the accumulation of stocks, since the international trade in timber has been running rather in advance of demand in the main importing countries. It does not seem likely in the opinion of the Commission that changes will be more than marginal, however, and they are satisfied that the continued demand for pulp and paper throughout the world is sufficiently buoyant to justify the new capacity which is now under construction or at the planning stage in Finland and Sweden.

The increased trade between Eastern and Western Europe which has been apparent over the last three years has continued. Exports of sawn wood and pulp wood from Eastern to Western European countries increased by more than half in the first quarter of this year compared with the same period of 1954. On the other hand, exports of pit-props dropped to less than a quarter of their previous level. The decrease in political tension since the Geneva conference should pave the way for further increases in the timber trade across the Iron Curtain.

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THE PLIGHT OF COAL

The results announced by the National Coal Board for the second quarter of this year are the worst since the industry was nationalised and worse than was expected, for there was some hope that the increase in prices announced in July would serve to offset an anticipated cumulative deficit. In the event, as the April to June figures now published show, the deficit had achieved distressing proportions well before July. The financial deficit in the first half of 1955 thus works out at almost £24 million, bringing the deficit since the industry was nationalised to £41 million. The Board hopes to make up some of this loss in the second half of the year, when it will have the benefit of the price increases which became effective on July 18. When the price increase was announced the Board said that it expected its accumulated deficit to rise to over £32 million at the end of this year, after taking into account the additional yield from the higher prices. If this drop in the cumulative deficit from £41 million to £32 million is to be achieved there will have to be a remarkable improvement in the financial results in the second half of this year, an improvement which cannot be achieved without an equally remarkable improvement in output.

These gloomy results have been caused by lower output, higher wages and higher costs of materials and it is to be remembered that the financial cost to the industry of stocking coal and moving some of it by road will have to be borne by the account drawn up for the second half of the year. A substantial part of the deficit, however, is accounted for by the difference between the price of imported coal and the price at which it is resold by the Coal Board in this country.

The coal industry is caught up in a Gordian knot of rising costs and falling output. While it is true that the industry, like any other, has not complete control of the factors influencing its affairs, some of the changes recommended in the recent Fleck report could go some distance to improve the industry's position. Continued heavy capital investment is proving to be notoriously slow in producing results and only the optimists would expect a sudden improvement in the recruitment of manpower.

A good deal could be done, however, at management level to bring the impact of modern ideas on administration and management to have an influence on the industry. Sir Andrew Bryan, the member of the National Coal Board responsible for staff, spoke of these matters at the N.C.B. Summer School at Oxford last week. He had much to say on the need to encourage delegation of authority by managers and of the scope which existed to give managers a comprehensive training in administration and management. If progress can be made on these lines, and in particular if the desperately inadequate supply of highly skilled technicians with managerial ability could be put to the best possible use, the coal industry may yet develop an *esprit de corps* which will be seen in high output and better financial results.

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EQUIPMENT FOR APPLEBY-FRODINGHAM

An extension in the iron and steel industry's pig-iron capacity from 11 million tons in 1953 to 15 million tons by 1957 has been the outstanding feature of the recent stages of the iron and steel industry's development programme. Part of the pig-iron scheme for the whole industry was a £13 million blast-furnace modernisation plan by the Appleby-Frodingham Steel Company, Limited, a member of the United Steel Companies, Limited, group. This project was due for completion by 1955. Last year Appleby-Frodingham became the first British works to make more than a million tons of pig iron in a year. The actual figure in 1954, including ferrous alloys, was 1,037,540 tons, compared with 972,100 tons in 1953. The company also produced more than a million tons of steel last year for the second year in succession—again a unique performance.

The company have announced (page 408) that work has started on a £1·5 million project at its Scunthorpe works. A new turbo-blower, an additional open-hearth furnace and ancillary equipment are to be installed as well as an ingot stocking, handling and loading gantry. The turbo-blower is expected to be ready early in 1957 and is claimed to be the largest in the world. The fifth unit at the iron works, it will enable the company to boost output from its four blast furnaces. Recently, these achieved an output of 100,000 tons of iron in a four-week period, about 1,250,000 tons a year—a significant advance on the average weekly output last year and reckoned to be a world record for lean ores. An increased supply of air should enable even higher rates of production to be reached.

The new 350 ton capacity tilting open-hearth furnace is the third alongside two furnaces built in 1947. It is scheduled to produce about 120,000 tons of steel a year.

This Scunthorpe development is very much in line with the industry's basic plan to increase pig-iron output and the production of flat products.

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JOHN BROWN'S STRENGTH

John Brown and Company, Limited, belongs to that small group of engineering companies which early perceived the advantage of having one foot in the expanding steel industry of Sheffield and the other on Clydeside. This dual basic interest accounts not only for its strength to-day but also for the continuing expansion of its interests. Few companies have the prestige of John Brown in one particular field, namely shipbuilding, and also a widely drawn and successful group of subsidiary and associated companies which are household names in their own right.

Lord Aberconway's speech recently to the shareholders of the holding company underlined the successful trading experience of the financial year which came to an end last March. The shipyard and engine works of John Brown and Company (Clydebank) Limited, continue to be fully employed. The tonnage output has improved, following the improvement in steel supplies, and continued success for the Clydebank yards is typified by the fact that last year the two new Cunarders, S.S. Saxonia and S.S. Ivernia,

were completed and are being followed by two more passenger ships for the Cunard Steam-ship Company, Limited. Work on water turbines and gas turbines has continued to expand and good progress has been made on re-equipment at Clydebank. During the year, John Brown Land Boilers, Limited, became a separate company, having previously been a division of the Clydebank company, and this concern is well occupied with work for the Central Electricity Authority, the North of Scotland Hydro-Electric Board, and customers in the Dominions. Wickman, Limited, which is known as the largest specialised manufacturer in this country of multi-spindle automatic lathes and as a pioneer in hard metals, has had a successful year. So, too, has the boring and turning mill business of Webster and Bennett, Limited. Firth Brown Tools, Limited, found the demand for its products increasing, notably in the second half of the financial year and this increase has gone on while Cravens, Limited (who used to be known as Cravens Railway Carriage and Wagon Company, Limited) has had a record year. The order book of this company is the longest in its history and the order book of Markham and Company, Limited, of Chesterfield, is also in a very satisfactory position. A. C. Wickman in Canada has recovered from the depression in the local engineering industry following the cut in the rearmament programme. Westland Aircraft, Limited, has begun preliminary work on the development of a large helicopter, which has been named the Westminster and has been designed for two gas turbines and a 5-ton load of freight or 35 passengers. Further development of this aircraft now depends on securing sufficient orders. Work abroad done by Costain-John Brown, Limited, makes good progress both in the Dominions and in the Middle East, as well as in this country.

The chairman was able to say that the trading prospects for each company within the group appear to be good, provided the general economic situation remains stable. Certainly, John Brown has insured itself against the consequences of sharp fluctuations of trade to a remarkable extent in recent years by diversifying its engineering interests.

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P. & O. TANKER PLANS

The decision announced last week by the Peninsular & Oriental Steam Navigation Company Limited to embark on an extensive programme of tanker building is of wide significance. The sheer size of the programme makes it important to both the shipping and the shipbuilding industries, for it has preceded by a small margin the official announcements expected from the big oil companies of their own shipbuilding plans. P. & O. has already placed orders with British shipbuilding yards for 25 tankers costing £37 million at present prices. Seven ships are to be delivered in 1958, nine in 1959 and the rest in 1960. In the early part of the programme a few 30,000 ton vessels may be built but most of the fleet is to consist of ships of 18,000 tons or so. This will fit in with the general expectation that the oil companies will in future build large ships and will charter medium-sized tanker tonnage from general shipowners. The recent order by Esso Petroleum for two 36,000 ton vessels from Vickers-Armstrongs fits this pattern.

Since the war, shipbuilding yards both in this country and abroad have to a large extent depended for their prosperity on orders for tankers. More recently the tailing-off in tanker orders and the improvement in freight rates for dry cargo space have reduced, though not eliminated, the preponderance of tankers building in the yards. There have been signs until recently that replacement demand for tankers would be the main spring of new orders from this source for some time, but rumours of the latest plans of the oil companies and P. & O.'s decision to enter a new field with a programme of this dimension completely alter the picture. New tanker tonnage is going to play a vital part in the calculations of the shipbuilding industry, apart altogether from ships built for replacement. An important question now is whether P. & O.'s decision will prove to be infectious to other shipping companies for whom a medium-tonnage tanker fleet has attractions. Will their decision, in fact, cause all actual and potential builders of new tanker tonnage to assess the tanker position anew?

There is the added complication that shipbuilding yards are prosperous and that any more ambitious plans could not be put into effect either in British or Continental shipbuilding yards without something of a queue developing. It is by no means clear that the existence of such a queue, as opposed to the more orderly arrival of customers, would work out to the benefit of British shipbuilding as against the Continent. When the P. & O. fleet commences trading, possibly at the same time as new oil company tonnage, it will be an interesting development against what had appeared to be the long-term trend. The world tanker fleet amounts now to just over 40 million tons and there has been a tendency of recent years for registration of tanker tonnage to fall away in the United States and for it to increase in this country, in Norway and in other Western European countries. There has also been increased registration under the flags of Liberia and Panama. The P. & O. and other programmes will not, of course, increase U.S. registrations but it should increase U.K. registrations and so counteract the recent undesirable trend for a large amount of new tonnage to be registered in foreign countries as a matter of convenience and as a means of evading the better kind of international shipping convention.

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MOTORWAY DESIGN

Certain misgivings about the trend of thought on the design and use of motorways in Britain are accentuated by the paper read by Mr. J. A. Proudlove before the British Association and published in this issue of ENGINEERING.

It must certainly be made an offence for any vehicle to stop on the carriageway except in an emergency, but the idea seems to be gaining ground that the hard standing along the side of the road may be employed as a parking place. This will simply lead to multiple crashes through drivers braking too suddenly, or pulling out into the traffic stream without warning. Hard standing should be available where disabled vehicles can be placed until they are repaired or towed away, but parking must be restricted to proper lay-bys, with approach roads long enough to allow drivers to slow down only after leaving the traffic stream, and accelerate up to stream speed again before joining the main carriageway.

It is also somewhat alarming to hear of schemes for sight lines on hills or curves where "safety will demand a reduction of speed when in excess of 50 m.p.h.," particularly as in the same paper reference is made to design standards for the *Autobahnen* based on maximum speeds of 100 m.p.h. Our own experience with a modern fast car in Germany shows that cruising speeds up to 120 m.p.h. can be maintained for considerable distances without undue strain, and it is rarely necessary to drop much below 100 m.p.h. on curves, but humps on hills may demand a speed reduction to 80 m.p.h. purely because of the lack of vision.

For drivers of modern fast vehicles the vertical "corners" are now a much bigger problem than those in the horizontal plane. They are the worst feature of the otherwise good French main roads, for they demand rigid observance of white lines on hill tops, enforced by frequent police trapping. Even on a dual carriageway, humps demanding speed reductions to 50 m.p.h. may lead to accidents through sharp changes of speed and direction.

Finally, there is nothing in our experience as a race of individualists to suggest that we can afford to ignore the Continental policy of strict control of building design and specifications. Otherwise these expensive new roads are going to be lined with new slums: the ill-built shacks and untidy parking plots of the transport cafés.

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MAN-MACHINE RELATIONSHIPS

In designing and marketing engineering equipment it is not easy to leap ahead of competitors. It is not easy to pioneer a new trend which others, less imaginative, are compelled to imitate after a wasteful time lag. There is, however, an aspect of design which offers such an opportunity—one that has already been grasped in the design of equipment for the Armed Forces but has not been exploited anything like fully in industry. It relates to all instruments, machines, etc., that are operated or controlled by human beings.

The effective use of a machine depends to a large extent on the efficiency of the operating or controlling tasks, and these tasks arise from the relationship between the operator and the machine. A fuller understanding of this relationship—of the capabilities and limitations of the man and of the nature of the machine control that is required—permits the operating or controlling task to be "designed." It is a blend of engineering, psychology and physiology.

The Admiralty have encouraged this approach. As Mr. D. Wallis, of the Admiralty Research Laboratory, said in a paper to the British Association, "mistakes anywhere in handling controls or interpreting displayed information can nullify the potential value of technical equipment." In industry a split second may not be as important as in the Navy, but efficiency is certainly important in both. The science of ergonomics, as this amalgam of subjects is called, is fostered by the Ergonomics Research Society, believed to be the only society of its kind in the world. Its members have done valuable work in industry, but the science could be exploited much more—with advantage to those who take the initiative.

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CALLING ALL LUBRICATION ENGINEERS

If Great Britain is the only country in the world to have a society devoted to the science of ergonomics, as remarked in the previous note, she lags behind some others in not having a society concerned with lubrication. But plans are in hand to remedy the deficiency. A meeting held recently under the chairmanship of Mr. G. D. Jordan, M.Eng., A.M.I.Mech.E., decided to form a permanent "Group of Lubrication Engineers."

The objects of the Group were defined as: (*a*) to promote more effective recognition of the importance of the field of lubrication; (*b*) to assist in every possible way in developing educational facilities for lubrication—in industry, at universities, technical colleges, etc.; (*c*) to arrange technical meetings and discussions on lubrication and allied subjects; (*d*) to encourage the interchange of knowledge and experience between members.

There was some discussion on the form that the new body should take. The three possibilities considered were: a separate society on the lines of the American Society of Lubrication Engineers; affiliation to one of the existing major engineering institutions; or the formation of a permanent independent group. The reasons for selecting the last organisation have not been stated, but as the Group is to be permitted to "re-examine the position periodically," the inference is that the founders are concerned to ensure that it grows healthily, adapting itself to external influences and needs.

In the meantime, the Group would welcome comment and expressions of interest from engineers concerned with lubrication. Perhaps librarians and information officers could also comment, because it is they who have to handle such a high proportion of published technical literature. The address to write to is: The Group of Lubrication Engineers, c/o The Editor, *Scientific Lubrication*, Broseley, Shropshire.

The master control room at the television studios of Associated-Rediffusion Limited is responsible for the final output of the studios, for keeping programmes to schedule, and for inserting the filmed advertising announcements between programmes.

SPONSORED TELEVISION

THE TRANSMITTER AND A STUDIO

The London transmitting station of the Independent Television Authority was opened on September 13, and on September 22 the first full-scale programme services started. In addition to the normal engineering problems in building television studios and transmitting station, the construction engineers have been handicapped by a late start and the absolute necessity to transmit the first programme on a certain date.

The London I.T.A. network consists of a transmitting station at Beulah Heights, between Croydon and Crystal Palace; the studios of the programme contractors, the Associated Broadcasting Company for weekends and Associated-Rediffusion Limited for weekdays; and the post office lines connecting the studios to the transmitter. In this article are described one of the studios and the transmitter, and the transmission of a programme is traced from the studio floor to the I.T.A.'s aerial.

The Wembley studios of Associated-Rediffusion will consist of five studios, a telecine room, and a central control area. On one side of the control area are studio 1 and the site for studio 5, and on the other side are studio 2, now in use, and studios 3 and 4, which will shortly be completed. The control area is on three floors; on the ground floor are viewing rooms, camera control rooms for studios 3 and 4, lighting control rooms, sound locks, technical stores and workshops. On the first floor are vision, sound and camera control rooms for studios 1 and 2, and vision and sound control rooms for studios 3 and 4. There are also three announcers' rooms on this floor. On the second floor are the master control room, shown above, and two rooms for remote control of lighting in studios 1 and 2.

A number of programmes originate from outside events, and some from the telecine room, but the majority come from one of the studios. The technical equipment in a studio includes three television cameras, microphones and lighting equipment. These are adjusted by operators in the studio, but only on instructions through headphones from the control rooms.

The three cameras on the studio floor are always "alive," viewing the scene from three different angles and translating it into electrical impulses. These three separate sets of signals are fed by cables to the camera control room, where they are connected to individual camera control units, each manned by an operator. Above each camera control unit are two cathode ray tubes and controls; on one of these tubes the waveform of the camera signal appers, while the other reproduces an actual picture of what the camera is "seeing." The operator maintains careful and constant watch over both of these, adjusting for changes of lighting and thus ensuring a suitable picture for transmission. In this way the three cameras on the studio floor are controlled for picture quality.

VISION AND SOUND CONTROL : TELECINE

The vision control room overlooks the studio, and it is from here that the programme is produced. The producer sits at the control desk between the vision mixer on his right and the studio lighting control engineer on his left. The signals from the cameras on the studio floor are fed to three picture monitors, and from these the producer can select the one most suitable to his purpose at a given moment, and cause it to be routed on its way to the transmitter.

The switching and fading is done by the operator of the vision mixer. The vision mixers at Wembley are of the relay-operated type, which handle eight inputs; they consist of two rows of push-buttons, the A and B rows, between which fades can be made or superimpositions produced, feeding into a third row of buttons used for cutting from camera to camera and cutting in and out of the A-B bus system. The operator of the vision mixer can also remotely control the telecine projectors when filmed inserts are required in the programme. The lighting control engineer is in constant touch with his switch-board, which is on the second floor in the case of studios 1 and 2.

The sound control room is separated from the vision control room by a double glass window, but also overlooks the studio. The sound mixer faces a console upon which are mounted faders, which control the outputs of the various microphones used in the studio; each microphone can be faded in or out at will. The sound mixer is responsible for maintaining the continuity of sound from the studio to match the producers' pictures in the vision control room. He is also responsible for the technical aspect of the interpolation of announcements from the announcer's booth, and for the introduction of recorded music or sound into the programme as required.

The telecine equipment is installed on the ground floor, but can be remotely controlled either by the vision mixer or master control. It consists of 16 and 35 mm. flying spot equipment made by Electric and Musical Industries, Limited, Dawley Works, Hayes, Middlesex, and the R.C.A. Vidicon equipment, which can show miniature slides and small opaques as well as films. The telecine apparatus can be used for complete films, for film inserts in programmes, or to introduce captions and advertising announcements.

MASTER CONTROL ROOM AND BEYOND

The output signals from the vision and sound control rooms pass to the master control room, and the master controller is responsible for the studio output. His prime function is to detect the outputs of the various studios and remote telecast units to build up a complete day's programme, inserting the filmed advertising announcements to a precise time schedule. The master control equipment, part of which is shown in the illustration, provides for the simultaneous switching of sound and vision from eight input channels to two transmission channels, with adequate previewing facilities. A wide range of standard test signals is provided for passing to the line for adjustments before transmission commences, and two monoscope cameras provide the familiar setting-up signals.

Output from the studio travels by post office coaxial cable to the Museum telephone exchange. A number of cables come in to this exchange from the various studios of the contractors and elsewhere. From Museum a cable runs to the Livingstone exchange, and from there another cable runs to the transmitting station at Beulah heights.

The transmitting station consists of the aerial, transmitter hall, control room, telecine room, emergency announcer's room, and offices. Most of the equipment was supplied by Marconi's Wireless Telegraph Company, Limited, Chelmsford, Essex, who also supplied most of the electronic and control equipment for Associated-Rediffusion's Wembley studios.

The vision transmitter has 10 kW maximum output and the sound transmitter 2½ kW. The vision apparatus consists of a 2 kW type BD. 357B transmitter and a type BD.360 amplifier. The transmitter is housed in four standard cubicles and the amplifier in three, all of which are bolted together to give a continuous front. The complete transmitter is designed to give a peak output power of 10 kW under vestigial sideboard conditions, at any chosen channel in the upper frequency band of 170 to 216 Mc., using the British standard 405 line system. Push buttons are provided on a transmitter control panel for normal operation of the transmitter, which may thus be brought up on power from the control desk. The voltage and feed of the final amplifier are metered. A black-level control and calibrated input attenuator are also provided on the control panel.

The telecine apparatus at Beulah Heights has been provided by Cinema-Television Limited, Worsley Bridge-road, London, S.E.26. The "Cintel" apparatus is of the single-channel flying spot type which will provide 20 minutes of film transmission. It provides a video signal to the B.B.C. standard of 405 lines, 50 frames per second, and operates under the control of the master synchronising waveform generator of the station.

The output of the station is fed into an 8-stack aerial array, which provides an effective radiated power of approximately 60 kW. Aerial height is 175 ft., the site height 375 ft., and the frequency 194·75 Mc.; the primary service area is expected to extend to Tilbury, Hertford, Chesham, Marlow, Guildford, East Grinstead and Gravesend, and the secondary service area between 5 and 20 miles further, according to the direction.

It is hoped that a second transmitter will be installed by December, 1955, and the two transmitters will be able to run in parallel, giving a peak effective radiated power of 120 kW. In event of breakdowns one set could transmit on its own, as now. In two years time the Crystal Palace aerial should be available and the power from that aerial is expected to be 200 kW.

SPECIALISTS VISIT THE SOVIET UNION

Steel and Building Delegations

The Soviet Government has invited two teams of specialists from the United Kingdom to visit undertakings in the U.S.S.R. and to exchange technical information. The first of these, a delegation from the Ministry of Housing and Local Government, the Ministry of Works, and the Building Research Station, left this country by air on Tuesday, September 13, and will remain in Russia for a fortnight to study Soviet methods of industrial and domestic building. The second, which set out on Wednesday, September 21, is a party of steel experts who attend meetings of the E.C.E. (Economic Commission for Europe) steel committee, and they are to spend about ten days in the Soviet Union viewing steel plants.

Both visits take place under the terms of a resolution of the United Nations Economic Commission for Europe sponsored jointly by the Soviet and United Kingdom governments, and both are return visits corresponding to tours made earlier by Soviet specialists. The members of the building delegation are: Mr. S. W. C. Phillips, Under Secretary for Housing, and Mr. J. H. Forshaw, Chief Architect and Housing Consultant, both of the Ministry of Housing and Local Government, Mr. M. W. Bennitt, Under Secretary for Building Industries and Materials Division, Ministry of Works, and Mr. R. C. Bevan, Head of Building Practice Division, Building Research Station. The guests of the Soviet Ministry of Ferrous Metallurgy are: Sir Robert Shone, C.B.E., executive member of the Iron and Steel Board, who is to lead the delegation, Mr. C. R. Wheeler, C.B.E., joint managing director of Guest Keen Iron and Steel Company, Limited, Mr. W. F. Cartwright, general manager, the Steel Company of Wales, Limited, Mr. A. Jackson, director and general works manager, Appleby-Frodingham Steel Company, and Mr. T. Dennison, technical officer, British Iron and Steel Federation.

DESIGN CENTRE

"A Pavilion of British Industrial Art"

It has recently been announced that the Design Centre—a permanent but changing exhibition of well designed British goods—is to be opened in the spring of 1956 at 28 Haymarket, London, S.W.1. All the goods displayed will be selected from Design Review, the Council of Industrial Design's photographic and sample record of commended articles, and manufacturers wishing to exhibit are urged to submit the products of which they are most proud for admission to the Review. Most of the 8,000 sq. ft. of floor area will be devoted to the changing display, but there will also be periodical popular and topical exhibitions addressed to different sections of the public or to particular trades. The main purpose of the Centre, however, will be to offer to home and overseas buyers a guide to the best durable consumer goods in current production by British industry.

Although articles of engineering interest as such will not for the time being be exhibited, the products of many engineering firms are nevertheless likely to be on view, and numerous engineering companies have already undertaken to support the Centre. Examples of the goods to be shown include: domestic appliances, lighting, cooking and heating equipment, radio and television sets, hardware, office equipment, building fittings and street furniture, as well as furniture, furnishings, textiles, floor coverings, tableware, travel goods and wallpaper.

It is intended that the Centre will be complementary too and not in competition with existing trade exhibitions, and that it will serve as a convenient West End focal point for those wishing to keep in touch with current trends, and where the public may look at leisure before buying in the shops. It is noteworthy that the exhibition will be different from other trade fairs in that the choice of articles for display will be made by an independent body.

The architects' department of the Ministry of Works are responsible for the interior of the building, and Nicholson Brothers, 29 Buckingham-street, London, W.C.2, have been commissioned to design the exhibition fittings. Ward and Austin of the same address have prepared a special treatment of street frontage with non-reflecting windows.

A NEW NIMONIC ALLOY

Further Creep Data for Existing Alloys

Preliminary data on a recently introduced creep-resisting material in the Nimonic series of alloys, produced and marketed by Henry Wiggin and Company, Limited, Wiggin-street, Birmingham, 16, indicate that this new alloy, Nimonic 100, may be used at temperatures some 30 deg. C. higher than those permissible for previous alloys in the series. At a temperature of 940 deg. C., the time to rupture the new material at a stress of 7 tons per square inch is not less than 30 hours, compared with 15 hours for Nimonic 95. At 980 deg. C., the stress to produce rupture in Nimonic 100 in 50 hours is 4 tons per square inch, rupture in 100 hours 3·5 tons per square inch, and rupture in 300 hours 3·0 tons per square inch. These figures are given in a new edition of the booklet, "The Nimonic Alloys: Design Data," issued by Henry Wiggin.

The composition of the new alloy is not stated but its hardness range, in the fully heat-treated condition, is given as being between 320 and 400 diamond-pyramid numbers, its specific gravity as 8·04 and its electrical resistivity as 132 microhm-cm. at 20 deg. C.

In addition to giving data on the new alloy considerable revisions have been made in the booklet in order to include the results of creep and fatigue tests obtained since the previous edition was issued. Thus 10,000-hour creep data for Nimonic 90 and 95 are included for the first time and the fatigue properties of Nimonic 80A, at 700 deg. and 750 deg. C., are indicated. Nimonic 80A is a material intended for applications in the temperature range 650 to 750 deg. C., and capable of use for relatively short time service in the range 820 to 850 deg. C., while Nimonic 90 has creep properties which render it suitable for service in the range 800 to 870 deg. C.

Long-time creep testing of the Nimonic 90 alloy has given some interesting results, a test piece stressed at 5 tons per square inch, and heated continuously at 750 deg. C., having shown a creep strain of less than 1 per cent. in the first 15,000 hours of the test.

Further creep and other tests on the Nos. 95 and 100 alloys will be awaited with interest by metallurgists and design engineers engaged in high-temperature applications.

DROP FORGINGS IN ALLOY STEEL

Informative Colour Film

A 16 mm. colour film with technical commentary entitled "Drop Forgings in Alloy Steels" has recently been made by the photographic section of the Brown-Firth research laboratories. It deals with the production of selected drop forgings—from the original steel bar or billet to the machined component—and shows in particular how the induced grain flow enhances the qualities of the finished article.

The first section of the film covers gas-turbine discs and factors affecting die design, emphasising the importance of using special forging-quality steels. The preparatory forging of the "cut pieces" is outlined, followed by drop forging, heat treatment, works and laboratory testing and inspection by non-destructive methods. The latest etch-inspection techniques are also featured.

Later scenes show the construction of helicopter rotor assemblies, a flying sequence of various turbine-engined aircraft, the drop forging of connecting rods for piston engines and the machining and assembly of a radial sleeve-valve aero engine. Other characters in order of appearance are a large marine Diesel engine, Nimonic gas-turbine rotor blades, a 52,500-kW steam turbo-alternator and two gas turbo-alternators (one of which was described in ENGINEERING, vol. 179, page 727, 1955). The film concludes with sections dealing with such special applications of drop forgings as cream separators, cotton-ginning machines, gate valves, cattle-food crusher beaters, rail ballast tampers, and finally the forging and assembly of gears followed by example of road vehicles in service.

Copies of the film, which is made continuously interesting by good editing, is well balanced in colour and subject matter, and is informative while employing a minimum of advertising, may be obtained on loan, free of charge, on application to Firth Derihon Stampings Limited, Sheffield-road, Tinsley, Sheffield, 9. The running time is 33 minutes.

* * *

FATIGUE OF METALS

London Course of Lectures

A course of twelve weekly lectures on the fatigue of metals is to be held at the Northampton Polytechnic, St. John-street. London, E.C.1, on Thursday evenings, at 6.45 p.m. and commencing September 29. Intended for engineers and physicists of graduate or equivalent standard, the lectures will cover research, development and design work involving considerations of failure under repeated loading.

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Letters to the Editor

THE ELAND ELIZABETHAN

Not a Flying Test-bed

SIR, We were interested to see a note entitled "S.B.A.C. at Farnborough" on page 291 of ENGINEERING, September 2.

However, we must draw your attention to the fact that the Eland Elizabethan airliner R.M.A. "Golden Hind" is not a flying test-bed, but a new version of a well-known and popular aircraft, which is to be handed over to B.E.A. for freight evaluation trials.

B.E.A. have taken the greatest interest in the conversion project and if the trials prove to be satisfactory there is every indication that they will convert their Elizabethan fleet to turbo-props.

Yours faithfully,
T. LACEY,
Publicity Department.

D. Napier and Son Limited,
Acton, London, W.3.
September 14, 1955.

PERSONAL

LT.-GENERAL SIR RONALD WEEKS, K.C.B., C.B.E., D.S.O., M.C., T.D. (chairman of Vickers Ltd.) will relinquish the office of chairman of English Steel Corporation Ltd., on October 1. MR. F. PICKWORTH will relinquish his present office of managing director of English Steel Corporation and will take over the office of chairman of that company; he will also join the board of Vickers Ltd. on October 1. Mr. Pickworth will be succeeded by Mr. W. D. Pugh as managing director as from the same date.

MR. T. E. WILSON, A.M.I.E.E., assistant electric traction engineer, British Railways, London Midland Region, Manchester, has been appointed assistant (electric traction and generation) to the chief mechanical and electrical engineer, London Midland Region, Derby.

Among the appointments on British Railways Central Staff, announced by the British Transport Commission, are two in the Carriage and Wagon Engineering Department. MR. W. VANDY, works manager, Wagon Works, Shildon, is to be assistant carriage and wagon engineering officer, and MR. W. RHODES, technical assistant, Carriage and Wagon Engineering Department, is to be assistant (carriage design).

MR. A. H. KENYON, M.I.E.E., has been elected chairman of the North-Eastern Centre of the Institution of Electrical Engineers for 1955-56, in place of MR. D. E. LAMBERT, who has tendered his resignation on assuming a new appointment which will take him from the area of the Centre.

MR. W. GOLDING, traffic superintendent for Messrs. Dorman, Long & Co. Ltd., Middlesbrough, has been appointed a member of the Transport Users' Consultative Committee for the North-Eastern area to represent commerce and industry. The appointment has been made by the Minister of Transport and Civil Aviation under the provisions of Section 6 of the Transport Act, 1947.

MR. F. A. POPE, a part-time member of the British Transport Commission, has been appointed a director of the John Bull Rubber Co. Ltd. The appointments of MR. M. GOLDSMITH as deputy chairman and joint managing director of the company, and of MR. S. PERRIN as joint managing director, have also been confirmed.

MR. J. T. SHARPLES, B.Sc., A.M.I.E.E., until recently manager of the northern-area board of Barlow-Whitney Ltd., process heating engineers, has been appointed manager of the firm's main plant at Bletchley, Buckinghamshire. Mr. Sharples is succeeded as district manager, northern area, by MR. G. H. TOLLER, who will continue to operate from the firm's northern office, at 32 Deansgate, Manchester.

MR. E. R. HILTON has been appointed an assistant to the sales manager of the British materials handling division of the Yale and Towne Manufacturing Co., Wednesfield, Wolverhampton, Staffordshire.

DR. A. M. BAXTER, M.Sc., now senior lecturer in the Department of Civil and Mechanical Engineering, Royal Technical College, Glasgow, has been appointed head of the Research Department of G and J. Weir, Ltd., Glasgow. The appointment will take effect from December 1.

MR. RICHARD MCCULLOUGH has been appointed managing director of Lumenated Ceilings Ltd., a subsidiary of Thermotank Ltd. Mr. McCullough, who has spent the last 30 years in the Middle East, was formerly senior partner in the firm of William Stapleton and Sons of the Suez Canal Zone and a director of Wills and Co. Ltd. He is retaining his seat on the board of Egyptian Aviation and Travel Services.

The directors of Birmid Industries Ltd., have announced three new appointments to boards of their companies as follow: MR. J. W. BERRY, joint managing director of Birmingham Aluminium Casting (1903) Co. Ltd.; MR. H. GOODWIN, joint managing director, Bimetals Ltd.; and MR. G. A. RIDER is to be commercial director of Birmingham Aluminium Casting (1903) Co. Ltd.

Metropolitan-Vickers Electrical Co. Ltd., has announced that MR. A. WALSH, Assoc.M.C.T., M.I.E.E., has been appointed Consulting Engineer (Patents). He succeeds MR. L. H. A. CARR whose retirement was noted in this column in our issue of May 13 last. The company has also appointed MR. S. ANDREW as assistant superintendent, transformer department, and MR. K. M. MILLER, A.M.I.E.E., as assistant superintendent, G-aisle Department.

COMMERCIAL

TUBE INVESTMENTS LTD., The Adelphi, London, W.C.2, announce, in conjunction with MURUGAPPA AND SONS, Madras, the formation of a new company, TUBE PRODUCTS OF INDIA LTD., for the manufacture, fabrication and manipulation of electric-resistance welded steel tubes. A building site of 80 acres has been acquired near Madras. The new company will operate in close co-operation with TUBE PRODUCTS LTD., Oldbury, Birmingham. Murugappa and Sons are already partners with Tube Investments Ltd., in the company TI CYCLES OF INDIA LTD.

P. I. CASTINGS (ALTRINCHAM) LTD., manufacturers of investment castings, have opened a London office at 69 New Cavendish-street, W.1. (Telephone: LANgham 7511). MR. P. G. CHAPMAN has been appointed technical representative for the Southern counties.

Arising from the merger of HORDERN-RICHMOND LTD., with PERMALI LTD., last year, new Manchester premises for both companies have now been opened at 3rd Floor, B Block, 89 Oxford-street, Manchester, 1. All inquiries in the Northern area for electrical, mechanical, chemical and textile components and materials should be referred to the new address. In addition, the above is also the address of the Northern Office of the newly-formed company, HYDULIGNUM-JABROC (TOOLS) LTD.

The Manchester office of the UNITED STEEL COMPANIES LTD., will remove on September 24 to larger premises. The new address is to be National Building, St. Mary's Parsonage, Manchester, 3. The telephone number remains unchanged, namely Blackfriars 3526. Mr. H. A. Wilkinson is manager of the Manchester office, which is responsible for the company's sales in Lancashire, Cheshire, North Wales and part of Staffordshire.

NORRIS INDUSTRIAL CONSULTANTS LTD., 3 Unity-street, College Green, Bristol 1, have established a research and development department equipped to undertake the computation of complex stress factors, development of industrial processes, development of electronic equipment, and the analysis of industrial equipment and processes for improved productivity.

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CONTRACTS

Oxygen and Nitrogen Plants. A further contract for a large oxygen-nitrogen plant to be installed at the Billingham Division of Imperial Chemical Industries Ltd., has been secured by the BUTTERLEY CO. LTD., Butterley, near Derby. The plant will produce 240 tons of oxygen and 400 tons of nitrogen a day, both of high purity. In addition to this contract orders already in hand include a 200 ton a day very high-purity oxygen plant for the Corby Works of Stewarts and Lloyds Ltd. Contracts for similar plants have also been secured from the Newport Division of the Steel Company of Wales Ltd., and British Celanese Ltd. Orders secured to date for various types of oxygen-nitrogen plants are now valued at considerably more than £1 million.

Power-Station Plant. The directors of the Hong Kong Electric Co. Ltd., have awarded the ENGLISH ELECTRIC CO. LTD., Marconi House, Strand, London, W.C.2, a contract valued at approximately 25 million Hong Kong dollars. This covers the construction of a power station to be known as the North Point " B " station and sited next to the existing power station. The ultimate generating capacity will be 180,000 kW., and the English Electric Company will supply, erect and set into operation a 30,000 kW 600 lb. per sq. in., 850 deg. F., 3,000 r.p.m. steam turbo-alternator set as well as the switchgear, the transformers and all the other electrical and auxiliary equipment. Generation will be at 11·8 kV., stepped up through a 37,500 kVA transformer feeding into the Hong Kong Electric Co.'s distribution network at 22 kV. The sub-contractors for the civil construction work are GEORGE WIMPEY & CO. LTD.; for the boiler plant, BABCOCK AND WILCOX LTD., and for the cables and cable accessories, BRITISH INSULATED CALLENDER'S CABLES, LTD.

Wire Rope. An order for the supply of wire ropes for the 22,500-ton Canadian Pacific liner Empress of England, a sister ship of the Empress of Britain, launched by H.M. The Queen earlier this year, has been entrusted to Martin, Black & Co. (Wire Ropes) Ltd., Coatbridge, Lanarkshire. The ropes ordered will weigh approximately 20 tons and will be over three miles long. They will be used, among other purposes, for towlines, mooring ropes and for davit equipments.

Aircraft. Two repeat orders for Heron Series 2 aircraft have been received by the DE HAVILLAND AIRCRAFT, ENGINE AND PROPELLER COMPANIES. One is from the Shell Petroleum Co. Ltd., which have placed an order for a second Heron of the special executive version. The other order has been placed by the West African Airways Corporation and concerns three Herons of the 14-seat air-line version. The Heron aircraft has an all-up weight of 13,000 lb. and is powered by four de Havilland Gipsy Queen 30 Mk. 2 engines, driving the firm's two-bladed constant-speed propellers. The aircraft has a normal cruising speed of 183 m.p.h., at 8,000 ft.

Radar. Venezuela is to equip four of her most important civil and military airfields with radar equipment manufactured by DECCA RADAR LTD., 1–3 Brixton-road, London, S.W.9. The firm's type-424 airfield-control radar has been ordered to be installed at Maiquetia, Puerto Cabello, Maracaibo and Barcelona airfields. Furthermore, two Decca type-41 storm-warning radars have been purchased to assist in the preparation of aviation weather forecasts.

The type-424 radar selecter has been developed to assist the approach to landing of aircraft during adverse weather conditions. This type of radar has already been supplied for civil airfields in Great Britain, South Africa, India, Southern Rhodesia and Iceland and is in service at the Ministry of Supply experimental establishments at Farnborough, Boscombe Down and Martlesham Heath. The R.A.F., British Commonwealth, French, Swedish and United States Air Forces are also using the type-424 radar.

A substantial contract has also been placed by the Admiralty with Decca Radar Ltd., for a new navigational radar for fitting into ships of the Royal Navy. The equipment will incorporate special features to meet the operational requirements of naval vessels and is designed, in particular, for manoeuvring and pilotage purposes.

Boilers. An order for three boilers and ancillary equipment for the Pretoria " B " power station, South Africa, has been received by YARROW AND CO. LTD., Scotstoun, Glasgow. The order is valued at upwards of £1 million. The seven boilers at present installed in the power station are all of Yarrow manufacture.

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SYMPOSIUM ON METAL-PHASE TRANSFORMATION

Arranged by the Metal Physics Committee of the Institute of Metals, 4, Grosvenor-gardens, London, S.W.1, a symposium on " The Mechanism of Phase Transformations in Metals " will be held at the Royal Institution, Albemarle-street, London, W.1, on Wednesday, November 9, from 10 a.m. until 5 p.m. The morning session, from 10 a.m. until 12.30 p.m., will be devoted to " Transformations of the Nucleation-and-Growth Type," and the *rapporteur* of the eight papers submitted will be Dr. H. K. Hardy.

The afternoon session from 2.15 until 5 p.m., will deal with " Martensitic Transformations," and the ten papers submitted will be presented by Dr. R. W. Cahn acting as *rapporteur*.

Those who desire to be present should apply to the secretary of the Institute for a registration form, and persons registering to attend, whether they be members of the Institute or not, will be supplied with a copy of the papers. A registration fee of 10*s.* is payable. Subsequently, the papers, together with a report of the discussion, will be published in the Institute of Metals monograph and report series.

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HATFIELD MEMORIAL LECTURE

At the invitation of the Council of the University of Sheffield, Dr. E. C. Bain, vice-president, research and technology, United States Steel Corporation, has agreed to deliver the 8th Hatfield Memorial Lecture. The subject of the lecture will be " Trends in Metallurgical Research in the United States," and it will be given at 6.30 p.m. on Monday, October 17, in the Firth Hall of the University. Admission will be by ticket only and application for these should be made to the Registrar, the University, Sheffield, 10.

Obituary

MR. F. G. SKINNER, O.B.E.

The History of Weighing and Measuring

We regret to record the death on September 7, at the age of 62, of Mr. Frederick George Skinner, O.B.E., B.Sc. (Eng.), a Deputy Keeper at the Science Museum, where his special study was the history of metrology, to which most of his 33 years of service had been devoted. The son of a regular officer in the British-Indian Army, he was born in India but received his education in London. His pupilage in civil engineering, with Mr. A. Scott, M.I.C.E., Westminster, was interrupted by the first World War, and he was commissioned in the Middlesex Regiment in September, 1914. He was promoted captain in 1916. In the battle of Arras in May, 1917, he was severely wounded and taken prisoner, eventually returning to England in an exchange of wounded prisoners. In 1918 he began the three years' course in civil and mechanical engineering at the City and Guilds College, obtaining his B.Sc. (Eng.) degree from London University in 1921.

In the following year he joined the staff of the Science Museum as an assistant in the Engineering Division. He was at first engaged in developing the Civil Engineering Collection, and was then given the additional task, in 1926, of organising the Weighing and Measuring Collection, which he built up from practically nothing to the best of its type in this country. As a result of his painstaking researches, he became a recognised authority on the history of metrology, and was the author of articles on the history of weighing and measuring published in *Chambers' Encyclopaedia*, 1950; in Vol. 1 of the *History of Technology* edited by Singer, Holmyard and Hall, 1954; and in the Proceedings of the Sixth Congress of the History of Science, held at Amsterdam in 1950. His work, scholarly and accurate, was an absorbing interest, and brought him the O.B.E. in the New Year Honours List of 1954.

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MR. HOWARD EVANS

Research Metallurgist

Mr. Howard Evans, who died on September 11 at the early age of 48, was superintendent of the research laboratory of the Mond Nickel Company, Limited, in Birmingham, and was born in 1907. He studied metallurgy at the University of Sheffield and obtained the Associateship in Metallurgy in 1930. He also received the Mappin Medal and Premium which is awarded annually to the most successful evening student in the final examination for the Associateship. After graduating, Mr. Evans was employed in the research department of the Metropolitan-Vickers Electrical Company Limited, Manchester, for some eight years.

In 1938, he joined the staff of the development and research department of the Mond Nickel Company Limited, as research metallurgist in the firm's Birmingham laboratory. In 1945, Mr. Evans was appointed principal assistant to the superintendent and on May 1, 1954, he succeeded Mr. H. W. G. Hignett as superintendent of the laboratory, on the latter's appointment to the board of Henry Wiggin & Company Limited to take charge of technical (metallurgical) control and development in all the Wiggin Company's plants. Throughout his career with the Mond Company, Mr. Evans had been associated with a wide variety of research projects in both the ferrous and the non-ferrous metal fields.

Mr. Evans was elected a member of the Iron and Steel Institute and of the Institute of Metals in 1945, and a Fellow of the Institution of Metallurgists in 1946. He was the author of many technical contributions to these and other societies on various metallurgical subjects. During the session 1954–55 he served as President of the Birmingham Metallurgical Society.

MR. M. G. BLAND, O.B.E.

Consulting Engineer

Mr. Maurice George Bland, O.B.E., M.I.C.E., M.I.E.E., who died on September 9 at the age of 71, was educated at Wellingborough and, after serving for three years with the Bryan Donkin Company, went to the Central Technical College, South Kensington, for his engineering training. He later served with W. H. Allen, Sons and Company, Limited, until he joined his uncle, becoming junior partner in the firm of Albion T. Snell and Partners. He remained with this firm till 1942, when he started a separate consultancy, being later joined by his son. He was consulting engineer at Olympia and to several hospital groups. During the 1914-18 war he served with the London Electrical Engineers, and eventually commanded the 26th A.A. battery. He was elected an associate member of the Institution of Civil Engineers in 1910, and a full member in 1932; the corresponding dates for the Institution of Electrical Engineers were 1911 and 1952.

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MR. P. W. PETTER

Beginnings of the British Oil-engine Industry

It is only a little over a year ago that we had to record the death of Sir Ernest W. Petter on July 18 of last year. We now regret to report the death, on September 15, of Mr. P. W. Petter, Sir Ernest's twin brother, at his home at Christchurch.

Percival Waddams Petter was born on May 26, 1873, one of the 15 children of James B. Petter, head of the firm of James B. Petter, general engineers, which had its headquarters at the Nautilus Works, Yeovil, Somerset. With his brother Ernest he received his education at private schools and at Mount Radford School, Exeter. In 1890 he began an apprenticeship at his father's works and three years later was appointed assistant manager. He took over sole management in 1895 and was admitted to partnership in the company in May, 1896, when a beginning was made on the production of oil engines to his own designs and patents.

Together with Ernest he had interested himself in the development of internal-combustion engines, mainly with the object of building power units for road vehicles. The brothers did indeed construct their first motor car in 1895 and claims have been made for this vehicle as the first British-built car propelled by an internal-combustion engine, though, as we noted last year, the Butler car of 1878 would seem to have preceded it. Several such vehicles were made and in 1897 Percy formcd a small company for the manufacture of oil and electric motor carriages; in 1900 the company was thriving and expanding, but it was becoming evident that there was a wider market for their engines in agriculture and general engineering, and eventually the motor-car side of the buiness was abandoned.

The company continued to develop and in 1914, when Percy applied successfully for transfer from associate membership to full membership of the Institution of Mechanical Engineers, between 600 and 700 men were employed. The expansion of the company, accompanied as it was by the production of whole ranges of oil engines and of ventures into the aircraft industry, was traced in our notice of last year, when we recorded some of the many innovations the firm of Petters introduced for the betterment of oil engines. The two brothers, as chairman and vice-chairman, maintained their interest in the company until 1937 when, on account of increasing age, they resigned and the late Mr. A. P. Good took over the chairmanship.

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We regret also to record the deaths of:

MR. FRED FISHER DOCKING, at Derby, at the age of 81. He founded the firm of F. F. Docking and Co., heating engineers, of Uttoxeter New-road, Derby, nearly 50 years ago.

MR. LESLIE NEWTON VINE on August 28 at the age of 69. He received his technical education at the Central Technical College, London, and was thereafter engaged with the General Electric Company of the United States, at first on the design of transformers and then in the sales and commercial departments dealing with the same equipment. He was elected an Associate Member of the Institution of Electrical Engineers in 1913.

MR. CHARLES ROBERT JULIAN, M.C., A.R.S.M., M.I.M.M., at Minas de Rio Tinto Huelva, Spain, on September 7, in his 59th year. Mr. Julian attended the Royal School of Mines, London, from 1919 until 1923, where he obtained a first-class Associateship in Mining. He joined the Rio Tinto Company in August, 1923, became chief mining engineer in October, 1931, and was appointed general manager on January 1, 1951. During 1954, the Rio Tinto Co. transferred the major portion of their assets in Spain to a new Spanish company, and Mr. Julian became a director of the new company and also representative in Spain of the Rio Tinto Co., London.

MR. FREDERICK CHARLES BUSH, at Carlton, near Nottingham, on September 12 at the age of 86. He was a former director and general manager of the Raleigh Cycle Co. Ltd., and had been associated with the firm since 1890. After his retirement from the Raleigh Co., Mr. Bush joined the board of directors of the Castle Engineering Co., Nottingham, and held the position of chairman at the time of his death.

MR. ERIC ANTHONY CHARLES BRANCZIK, A.M.I.E.E., on September 13, at the age of 43. Mr. Branczik was managing director of Film Cooling Towers (1925) Ltd., Lionel-road, Kew Bridge, Brentford, Middlesex. He was the only son of the late Mr. K. W. Branczik, founder of the firm.

MR. HERBERT CRUSE at Chippenham at the age of 67. Former director and general works manager of the Westinghouse Brake and Signal Co. Ltd., which he joined as an office boy over 50 years ago. He was a former mayor of Chippenham and was an alderman of the borough.

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PROPERTIES OF MATERIALS AT HIGH RATES OF STRAIN

London Conference in 1957

The Council of the Institution of Mechanical Engineers, in collaboration with its Applied Mechanics Group committee, is taking steps to organise a conference on the properties of materials at high rates of strain, to take place in London in March, 1957. The materials under consideration in this conference will include only those used in the manufacture of mechanical-engineering structures or elements, and will exclude fluids. The conference will take the form of the presentation and discussion of a series of papers; arrangements are being made to issue copies of these in advance. The meeting will probably last from two to three days. It is expected that the papers will be grouped under six main subject headings as follow:—(*a*) Metal Physics; (*b*) Experimental Techniques; (*c*) Wave Propagation Strain-Rate; Effects on Small Strains; (*d*) Metal Working; (*e*) Non-Metals; (*f*) Basic Properties.

The Council is ready to consider the publication of manuscripts submitted in connection with this proposed conference. So as to allow sufficient time for the refereeing of manuscripts, the latest date for submission to the secretary will be September 30, 1956.

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OVERHAUL BASE AT KARACHI AIRPORT

Work has begun on new and improved engineering facilities at the Karachi Airport headquarters of Pakistan International Airlines, and is expected to be completed in two years at a cost of over £400,000. The plant should provide a useful source of foreign currency for Pakistan, for many of the world's major aircraft operators maintain frequent services through Karachi, and the need for a major engine repair and check base there has long been felt. The engine base will begin operating in January next, and its programme will grow as construction progresses.

EXTENSIONS AT APPLEBY-FRODINGHAM

Iron and Steel Plant

New plant costing over £1·5 million is to be installed at the Scunthorpe works of the Appleby-Frodingham Steel Company, a branch of the United Steel Companies, Limited, Sheffield. The three main items of equipment comprise a turbo-blower for the blast-furnace plant, an additional open-hearth furnace and a steel-ingot stocking, handling and loading gantry.

Foundation work for the new turbo-blower, which will be the fifth unit of its type at the Appleby-Frodingham ironworks, has already begun, and the completion of the project is expected early in 1957. The blower is to cost £750,000 and it will be capable of delivering 150,000 cub. ft. of air per minute to the blast furnaces at a pressure of 35 lb. per sq. in. A 20,000 h.p. steam turbine will drive the blower. The consulting engineers for this scheme are the Parolle Electrical Plant Company, Limited. Foundation work is being carried out by Holst and Company, Limited, and the structural steelwork is to be supplied and erected by the United Steel Structural Company, Limited. C. A. Parsons and Company, Limited, are supplying the turbo-blower and John Thompson Water Tube Boilers, Limited, will provide the boiler.

The additional open-hearth furnace, a 300 to 350 ton tilting unit, is being installed in the Frodingham melting shop alongside two furnaces laid down in 1947. The new furnace and its ancillary equipment will cost £800,000; it will be built by the Wellman Smith Owen Engineering Corporation, Limited, and will produce about 120,000 tons of steel annually. Most of this output will be supplied to the Steel, Peech and Tozer branch of the United Steel Companies; their new medium continuous-strip rolling mill on the Brinsworth site will ultimately absorb much of the extra steel produced. Like the new turbo-blower, the furnace is scheduled to commence operations in the early part of 1957.

An extension is being made to the Frodingham melting shop to accommodate the new furnace, and the building steelwork will be fabricated and erected by the United Steel Structural Company, Limited. Slight modifications are proposed for the uptakes and for the area at the ends of the new furnace, as compared with the two existing units. It is hoped that these modifications will lead to longer roof life and reduced refractory wear.

Designed primarily for firing by cold coke-oven gas and pitch creosote, the new furnace can also be fired by mixed gas if necessary.

To enable the additional steel ingots produced to be handled and loaded, an open gantry, 380 ft. in length and 110 ft. in span, is to be built at a cost of £100,000. It will be equipped with a seven-ton electric overhead travelling crane supplied by the Butterley Company, Limited. In this case also, the structural steelwork will be fabricated and erected by the United Steel Structural Company, Limited.

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FUEL EFFICIENCY EXHIBITION

The third post-war Fuel Efficiency Exhibition will be held this year at the City Hall, Manchester, and will be opened on October 12 by Sir Miles Thomas, D.F.C., M.I.Mech.E. Nearly 100 firms will demonstrate solid and liquid fuel economy for all branches of industry, and there will be displays by the Atomic Energy Authority and the Central Electricity Authority. The sponsors of the exhibition are the National Industrial Fuel Efficiency Service and the Combustion Engineering Association. The Combustion Engineering Association are holding a conference in connection with the exhibition; at 10.30 a.m. on October 13, Mr. F. C. de Paula will give an address " The Cooling of Steam," and at 10.30 a.m. on October 14, Mr. R. P. McCulloch will give an address, " Cutting the Cost of Steam."

BOOKS RECEIVED

Some of the books noticed here are selected for extended review in ENGINEERING.

The Plastic Moduli of British Standard Rolled Steel Joists. *British Welding Research Association, 29 Park-crescent, London, W.1.* (2*s.* 6*d.*)

The design of steel structures using the plastic theory developed by Professor J. F. Baker at Cambridge, is becoming more and more the accepted method in the drawing office. This memorandum tabulates the plastic moduli (for both the major and minor axis) of the full range of B.S. rolled steel joists; modified values of the moduli are given to take account of the presence of axial loading Worked examples illustrate the use of the tables for typical design problems, and the computation of the plastic moduli for plated joists is also explained.

Pakistan. Overseas Economic Survey. By F. G. ARNOLD. Published for the Board of Trade, Commercial Relations and Exports Department, by *H.M. Stationery Office, Kingsway, London, W.C.2.* (10*s.*)

In this latest edition in the series of Overseas Economic Surveys, Mr. F. B. Arnold says that the Pakistan Government is determined to put through its long-term development programme, with such foreign aid as it can muster. If industrial development brings about an increase in the standard of living, as is hoped, a demand should arise for many classes of goods which at present are denied to the market or are available in insufficient quantities. The author states that the key to Pakistan's development is power, and in view of the Government's dependence on overseas countries for heavy electrical plant, the demand for such equipment is likely to be considerable. Details of the industries in which the Pakistan Government welcomes the participation of foreign capital, and hints to exporters are also given in the booklet.

The Spot Welding of Aluminium and its Alloys. *British Welding Research Association, 29 Park-crescent, London, W.1.* (5*s.*)

This report examines the various requirements for both commercial and high-quality (to aircraft standards) spot welding of aluminium and its alloys. Sections of the report deal with the various welding machines available in Great Britain, the surface preparation of aluminium and its alloys before welding, joint design, strength and inspection of welds, weld defects and machine maintenance.

Mullard Ferroxcube. *Mullard, Limited, Century House, Shaftesbury-avenue, London, W.C.2.* (7*s.* 6*d.*)

Ferroxcube is a non-metallic magnetic ferrite, used as a core material for inductors and transformers. This book gives details and properties of various grades of Ferroxcube so that engineers and designers can select the right type for a given application. A detailed account of applications is included, among them pot-cores, transformer-cores for communications and television, aerial rods, and special components.

BEAMA Guide to British Arc Welding Electrodes. BEAMA Publication No. 144, 1955. *The British Electrical and Allied Manufacturers' Association, 36 and 38 Kingsway, London, W.C.2.* (5*s.*)

This is a revised and enlarged edition of a guide which has for long been a source of reference for those requiring information on the metal arc welding electrodes manufactured in this country by members of the British Electrical and Allied Manufacturers' Association. Information is now included on electrodes for welding high-tensile steels, corrosion and heat-resisting steels, cast iron, aluminium and its alloys, bronze, nickel and its alloys, and for hard surfacing. There are, in addition, notes on the application of these electrodes.

As before, British and American systems are described and summaries of the British specifications and Lloyd's regulations for arc welding electrodes are given. There is also an up-to-date classified list of mild-steel electrodes showing the British and nearest equivalent American code numbers and any Admiralty, Ministry of Transport or Lloyd's approvals, where these apply.

Principles and Practice of Electrical Engineering. By ALEXANDER GRAY. Seventh edition, revised by G. A. WALLACE. *McGraw-Hill Book Company, Incorporated, 330 West 42nd-street, New York 36, N.Y., U.S.A.* (7.50 dols.); and *McGraw-Hill Publishing Company, Limited, 95 Farringdon-street, London, E.C.4.* (56*s.* 6*d.*)

This book has been written primarily for students who are specialising in branches of engineering other than the electrical. Although generally elementary in treatment the chapters dealing with alternating current machinery and electronics reach a rather higher level. The present edition has been thoroughly revised and considerably expanded.

The Automatic Factory—What Does It Mean? Report of the Conference held at Margate, June, 1955. *The Institution of Production Engineers, 10 Chesterfield-street, London, W.1.* (25*s.*)

This report contains the papers presented, the opening and closing addresses, the discussion group reports, and a review of the display of automation equipment. A summary of some of the papers presented was given in ENGINEERING, June 24, page 780.

Units of Weight and Measure: Definitions and Tables of Equivalents. U.S. National Bureau of Standards Miscellaneous Publication 214. *The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A.* (40 cents.)

The units of length, area, volume, capacity, and mass in use in the United States are defined. Tables of interrelation and tables of equivalents for these units in the metric system and in the United States customary system are given. There is a section in which the fundamental equivalents are stated, one containing the approved spelling and abbreviation of each of the most common units of weight and measure, and one showing the status of the metric system in the United States. All of the tables and other material have been revised to conform to the definitions, equivalents, and usages current at the date of issue. The conversion tables are confined to simple units, excluding all compound units such as foot-pounds, pounds per cubic foot, and feet per second.

Symposium on Methods of Testing Building Constructions. A.S.T.M. Special Technical Publication No. 166. *American Society for Testing Materials, 1916 Race-street, Philadelphia 3, Pennsylvania, U.S.A.* (2.75 dols.)

This symposium was sponsored by A.S.T.M. Committee E-6 on Methods of Testing Building Constructions, and was presented at the 57th Annual Meeting of the Society at Chicago, in June, 1954. Seven papers on testing, evaluation, and performance of building construction are presented, some of the conclusions being based on research results or factual evidence, and others being expressions of the author's opinion. The papers presented are: Why Test Building Constructions; Structural Performance Requirements in Housing Codes; Transverse Strength of Masonry Walls; Fire Tests of Building Structures and Materials and their Utilisation in Building Code Requirements; History and Bibliography of Wood Diaphragm Tests; Glued and Nailed Roof Trusses for House Construction; and Lateral Tests on Full-scale Lumber and Plywood-Sheathed Roof Diaphragms.

The Organisation of Applied Research in Europe. Proceedings of the Conference held at Nancy, October, 1954. *Organisation for European Economic Co-operation, 2 Rue André-Pascal, Paris, 16e.* (600 francs); and *H.M. Stationery Office, Kingsway, London, W.C.2.* (12*s.*) (Reviewed on page 409.)

Science and Civilisation in China. Vol I: Introductory Orientations. By JOSEPH NEEDHAM, F.R.S., with the research assistance of WANG LING. *Cambridge University Press, Bentley House, 200 Euston-road, London, N.W.1.* (52*s.* 6*d.*) (Reviewed on page 370, in the issue of September 16.)

Mechanical and Electrical Engineering: Classified List of Historical Events. Published for the Science Museum by *H.M. Stationery Office, Kingsway, London, W.C.2.* (2*s.*) (Reviewed on page 370, in the issue of September 16.)

Géologie des Barrages et des Aménagements Hydrauliques. By M. GIGNOUX and R. BARBIER. *Masson et Compagnie, 120 Boulevard Saint-Germain, Paris, 6e.* (2,800 francs.)

This work deals with the geology of dam constructions and their hydraulic equipment. The book contains 176 figures and 28 plates. An explanation of each figure is given in English and it is stated that it is hoped that this will enable English-speaking readers to obtain a general idea of the subject matter. In this way the amount of translation necessary can be restricted to those sections that are of particular interest to each individual. In the 28 plates there are reproduced photographs of existing dams, or dams in course of execution, or their surroundings. The work contains elaborate discussions of matters pertaining to the geology of the sites of many dams, extensively illustrated by figures. The sinking of boreholes and the requisite machinery are also discussed.

Book Reviews

BLINDED BY SCIENCE

The Organisation of Applied Research in Europe. Proceedings of the Conference held at Nancy, October, 1954. *Organisation for European Economic Co-operation, 2 Rue André-Pascal, Paris, 16e.* (600 francs); and *H.M. Stationery Office, Kingsway, London, W.C.2.* (12*s.*)

Sir Henry Tizard, in his presidential address to the British Association at Brighton in 1947, and on several other public occasions, stated that it was not so much more research that was needed in this country as more ability to apply, effectively, the results of present and past research. The Duke of Edinburgh, opening the British Association meeting in Edinburgh, expressed a very similar opinion. Many others have been saying the same thing for some years past, but in spite of this the research industry, as it may now be well called, grows apace. No objection could be taken to this if the effective application was proceeding at an equal rate; but one cannot avoid the impression, which is strengthened by reading this report, that it is not. The balance of energies, talents, and abilities seems to be tipping heavily down on the side of organisation, direction, and management of research as an activity in its own right, rather than on the side of the work itself and its actual results—the real objects of the exercise.

A factual statement of the way that research is actually carried on in an establishment, e.g., that dealing with the British Cotton Industry Research Association, makes good reading, and it is interesting and useful, but too much time seems to have been spent in rather vain theorising as to how research might, or should, be done. There was the widest imaginable variety of views as to what " research " really was; whether, for example, Pasteur's dictum that there is no applied science (" There is science, and there are applications of science, the one issuing from the other as fruit from the tree that bears it ") is valid; or whether, as stated in other papers, science or research could be split up into two, three, or more categories depending on its degree of applicability to material things; or whether research, development, and application constitute a continuous and unbroken sequence.

As the title is *The Organisation of Applied Research*, the time, space, and printing wasted on this discussion savour rather of the theological disputations of the Middle Ages, and make the report rather heavy reading, which the occasional glimpses of light and reason hardly repay. The engineer will, however, welcome the statement by the chairman on page 178: " The advantages which make one article superior to another similar article generally arise not from any great difference in manufacturing technique but from a more up-to-date design, a better mechanism, or something which makes the article unique. This is due to the ability of the engineer, the drawing office or laboratory of the firm and also the time and money spent on the process."

It is no doubt a serious heresy to criticise or belittle research, but one cannot help thinking that it may be overdone, particularly as regards organisation and other ancillary activities connected with it. There is many a good tune played on an old fiddle, and many of the more important pieces of research have owed less to organisation than to inspired leadership, without which organisation can do little. Too much organisation tends to destroy that spontaneity which is an essential element in all creative work. There have been a number of cases where very promising work has been cut short before full development by over-organisation.

Professor Centola's short but impressive paper gives an objective resumé of the whole problem. The following is typical: " In a large number of higher institutes, research tends to become an end in itself and is used to supply material for articles intended to boost the personal standing of their authors; it thus becomes barren. On the other hand, the great industries tend to undertake research in their private laboratories with a great array of equipment, but sometimes with results which are disproportionate to the generous efforts of all concerned."

It may be significant that Switzerland, the country with perhaps the greatest success in the effective application of research, was represented by only one delegate. The countries represented were (with the numbers of their delegates): Austria (2), Belgium (9), France (16), Germany (8), Italy (12), Netherlands (4), Norway (1), Sweden (10), Switzerland (1), United Kingdom (16), Australia (1), Canada (1), India (1), Rhodeisa and Nyasaland (1), Union of South Africa (2), and the U.S.A. (6). Research associations and universities carrying out research work were much more heavily represented than organisations which might eventually use and apply the results.

The production of the volume is first class. One can only admire the devoted work put into the preparation of the papers, the organisation of the meeting, the translations involved, and the publication of the report, but after all this one can well say, to misquote Maréchal Bosquet watching the charge of the Light Brigade at Balaclava: " *C'est magnifique, mais ce n'est pas* ' engineering.' "

Profitable Small Plant Management. By MALCOLM H. GOTTERER. Published by Conover-Mast Publications, Incorporated, and distributed in Great Britain by *Bailey Brothers and Swinfen, Limited, 46 St. Giles High-street, London, W.C.2.* (44*s.*)

One reason for the reluctance of employers to engage specialists in each branch of factory management is the fear of increasing overheads. It can amount to an obsession in the minds of some employers but it is woefully short-sighted: it encourages rule-of-thumb methods, and when results are disappointing the blame is frequently laid on the operator.

Better results are achieved by more intelligent management. Although the author has called his book *Profitable Small Plant Management*, the principles outlined are basic, and apply to factories of all sizes. It is the degree of refinement of application that must vary with size, and therefore the author has been careful to outline his subjects both simply and with alternative methods of application.

The Productivity Council report entitled " Industrial Engineering " emphasised the need for a higher standard of management. It is perhaps a pity that the title of this report was not " Industrial Management," or as the author of the book under review prefers, " Scientific Management," for it would then have appealed to managers who are not engineering minded; there are many such in large and small businesses where engineering plays a secondary but important part.

When a business graduates in size from small to medium, a common failing is to mix control of current production schedules with that of future production schedules. Day-to-day problems then overshadow planning, creating future bottlenecks, and thus perpetuating a state of muddle. The author's chapter on production control is particularly comprehensive, especially in relation to job production, in which he outlines seven basic steps. Mass production control is included; rightly, because it is the product, not the size of the factory, that dictates the method of control.

On the subject of organisation, stress is laid on the need to organise duties, not men, so lessening the risk of deviation due to personalities. In this respect a job write-up is advocated, which at first sight seems superfluous, but if each member of a staff attempted to describe his duties, in detail, he would learn much about his job.

" Time and motion study " has become a hackneyed expression which is often discussed glibly and forgotten. In fact they are two separate and very different functions, and as the author clearly explains, the former cannot be attempted until the latter has been established. On the subject of incentive schemes, the better known are outlined, the author appearing to prefer those that put incentives on a time rather than cash basis, especially for job production. Indirect labour incentives are not recommended for small factories. The importance of good storekeeping is often overlooked, again because of the non-productive labour involved, despite the fact that it is highly probable that much more money is lost in wasted material than is saved in wages.

Some practices that could never be established in this country are described, but the author deals very effectively with suggestion schemes, and explains why many fall into disuse. He has dealt thoroughly with each aspect of management, and this fact may give the impression that his doctrines are too idealistic to be practical. This is not so. The true value of the book lies in the understanding and practical application of the principles involved and not in the blind copying of the author's theories.

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TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Conveyor Tensioner. LINK BELT CO., 307 North Michigan-avenue, Chicago 1, Illinois, U.S.A. Improved version of device for taking up slack in conveyors of most types. Consists of a bearing block mounted on a runner with a hinged top frame, and positioned by a threaded rod. Available for shafts from 1 $\frac{15}{16}$ in. in diameter to 3 $\frac{15}{16}$ in., with 30-in. adjustment. White-metal, ball or roller bearings can be fitted in the block. Folder No. 2539.

Fire-Retarding Board. WARERITE LTD., Ware, Hertfordshire. " Novopan," Danish laminated board for making structural, insulating and fire-retarding divisions in ships, now approved by Ministry of Transport and Civil Aviation; Novopan " B " of synthetic resin-bonded wood fibres and layers of asbestos, surfaced with veneers; Novopan " FX," as " B " but without asbestos. Booklet with installation drawings.

Surface Roughness Scales. RUBERT AND CO. LTD., Chapel-street, Stockport-road, Manchester, 19. Measurement of surface roughness by testing with fingernail and comparing with set of standard scales; set of 10 in plastics and leather case, set of 30 in box, graded in micro-inches C.L.A., British Standard. Illustrated leaflet.

Reducing Valve. SIR W. H. BAILEY AND CO. LTD., Patricroft, Lancashire. Class G3 pilot-operated reducing valve to deliver constant reduced pressure irrespective of fluctuations in inlet pressure; outlet pressures 1 to 125 lb. per sq. in.; applications, dimensions, construction and method of operation. Illustrated pamphlet.

Distribution Switchgear. LANCASHIRE DYNAMO SWITCHGEAR LTD., St. Stephen's House, Victoria Embankment, London, S.W.1. Metalclad heavy-duty fused switches, flush-fitting heavy-duty switches, unit-to-unit metalclad switchboards, flush-fitting cubicle switchboards; dimensions, ratings and applications. Illustrated booklet.

Porcelain Insulators. DOULTON AND CO. LTD. Doulton House, Albert-embankment, London, S.E.1. Booklet describing the manufacture of porcelain electrical insulators, at Tamworth. All the processes are illustrated and described, and there is a section on testing, both mechanically and electrically.

Ball and Roller Bearings. RANSOME AND MARLES BEARING CO. LTD., Newark. Over 200 types of ball and roller bearings with bores from $\frac{1}{8}$ to 15 in. and 4 to 200 mm. Catalogue also includes technical section dealing with such questions as selection, fitting and lubrication.

Roller Mills. INTERNATIONAL COMBUSTION LTD., 19 Woburn-place, London, W.C.1. " Raymond " roller mills with pneumatic feed control, cyclone collectors and double-cone separators. Several sizes. Brochure 9556.

MOTORWAYS*

SPECIAL ROADS FOR SELECTED TRAFFIC

By J. A. Proudlove, M.ENG.†

Although the title of this communication is "Motorways" the extended title should make it clear that much of what I have to say applies also to expressways, so first I should like to explain the fine difference between these two kinds of road. Motorways can be expressways, indeed we all hope that they will be, but an expressway may not necessarily be a motorway which is the name in common usage for what should strictly be called a special road. The difference is that a special road may be used only by certain classes of traffic and undesirable traffic can be denied access. It is certainly not a highway for the free passage of all Her Majesty's subjects in the ordinary sense.

Some of the history of road legislation and construction might be of interest. Prior to the Highways Act of 1835 highways were maintained by statute labour to the direction of local road surveyors. In addition there were privately sponsored turnpike trusts which were created under particular Acts of Parliament, the last trust operating until 1895. Highway districts were created in 1862 but it was not until the formation of the County Councils in 1888 that effective highway authorities were established. At this time all highways were regarded as local commitments, there was no central authority nor any Exchequer grant. In 1903 a Departmental Committee on Highways recommended the establishment of national roads and an authority with powers of compulsory acquisition of land for widening and realigning roads. The Committee also recommended construction of by-pass roads to relieve traffic congestion in towns, but no action was taken. A petrol tax and an increased motor-vehicle tax were levied in 1910 for the Road Improvement Fund to improve alignment, allay the dust nuisance and build roads. A Road Board was set up to carry out this work and to build roads primarily intended for motor traffic to which the general speed limit of 20 m.p.h. would not apply. Although the Board was very successful in solving the dust problem, no new roads were built but several of the proposals initiated by the Board were carried out subsequently—the Great West-road and Croydon By-pass.

In 1919 the Ministry of Transport was created as a central authority to co-ordinate road, railway and canal transport. The first appreciable amount of construction was started in 1924 when many arterial roads were built as unemployment relief schemes, monies were made available for a great mileage of new roads, and the Mersey Tunnel was commenced. Work on new roads was stopped in 1926 at the request of the Treasury, and in 1929 a Royal Commission on Transport found itself "unable to support any large expenditure on new arterial roads" but recommended that some by-passes be built. About this time an International Road Congress was held in Italy to inspect the new *autostrada* which had been built there, delegates from this country returned filled with admiration. The general 20-m.p.h. speed limit was removed by the 1930 Road Traffic Act and construction of by-passes was resumed during the depression in the same year. By the Trunk Road Act of 1936 the Minister of Transport became the Highway Authority for the newly-designated trunk roads which, in effect, became the first national roads centrally administered.

In 1938 the County Surveyors' Society made proposals for about 1,000 miles of "Motorways," and in 1946 the Minister submitted to Parliament a ten-year highway programme and a plan for a network of motorways and major routes to be improved. Legislation to allow construction of roads reserved for special classes of traffic followed in 1949 when the Special Roads Act received Royal Assent. This Act allows for the construction of special-purpose roads or the declaration of existing roads as special-purpose roads and defines groups into which traffic may be classified.

The situation at present is that the legislation to construct special purpose roads has passed Parliament and a basic plan for about 800 miles of these roads has been approved by the Minister. Most of the road lines have been surveyed in detail and in some parts the line has been published. The work of preparation of schemes under the Special Roads Act is generally carried out by the Local Highway Authorities, usually County Councils. As can be seen from the map, Fig. 1, the scheme proposes three main express routes, London to Carlisle, London to South Wales and Bristol to South Yorkshire, all to be constructed as motorways, with other roads improved to become all-purpose expressways radiating from London and connecting the principal cities with the motorways. Part of the west-east road from Liverpool to Hull is also expected to be built as a motorway, as is the "Ross Spur" which will form a part of a direct link from South Wales to the Midlands.

These chosen routes follow closely the earlier County Surveyors' Scheme and have been sited so that they may best suit all the major centres of population and industry. Birmingham and the industrial Midlands lie at the centre of a radiating system extending to London and the principal centres of industry, Lancashire, South Yorkshire and South Wales. Similarly the motorways are to extend to the ports or the ports will be linked by expressways to the motorway system. The three main motorways will parallel already existing lines of communication, the intention being that the motorways should be expressways for long-distance traffic while the existing roads revert to purely local needs. It is not intended that the special-purpose roads shall be constructed for the needs of high-speed traffic but rather long-distance traffic, though it is hoped that traffic speeds will be considerably raised on both local roads and expressways by the segregation of local and long-distance traffic.

DESIGN OF MOTORWAYS

It is probable that most of the motorways will be constructed to carry only vehicles in class I as defined by the second schedule to the Special Roads Act in normal peace-time conditions, that is pneumatic-tyred motor vehicles which are not required to travel at less than 20 m.p.h. by the 1930 Road Traffic Act. Thus pedestrians, pedal cycles, horse-drawn traffic and traffic travelling at less than 20 m.p.h. will be prohibited and will use the parallel existing all-purpose roads. In consequence, the motorways must be designed for traffic of which a large proportion will be heavy commercial vehicles and the pattern of road users will fall into two fairly distinct groups. The first will consist mainly of commercial vehicles travelling at speeds of 40 to 45 m.p.h. and the second of private cars which will probably travel at speeds between 50 and 70 m.p.h.

Although enough is known of the existing traffic flow patterns and the rate of increase of vehicular traffic to make a reasonably accurate estimate of the traffic demand for a motorway in 10 or 20 years time, it is still necessary to determine a layout which will satisfactorily accommodate these demands. A great deal of research into the effects of various aspects of road layout and traffic conditions has been carried out in recent years, particularly in the United States of America, and the results of this work will no doubt be applied to the design of British motorways.

The aim of the designer in this country must be to design a road which will be justified economically, unlike the early Italian *autostrada* which were intended to carry cars at very high speeds. Our roads must be capable of carrying large volumes of traffic at reasonably high speeds and their design involves the study of traffic flow and factors affecting traffic flow. It can be expected that for long periods vehicle speeds on the motorways will be affected by high traffic flows, and that most vehicles will travel at a "stream speed." Complete freedom of choice of speed will only occur on occasions when there is little traffic, when the construction of the road may be an inducement to high speeds. Fortunately the relationship between lane capacity and vehicle speed is such that traffic capacity is greatest and reasonably constant for stream speeds between 30 and 55 m.p.h. Thus it is an

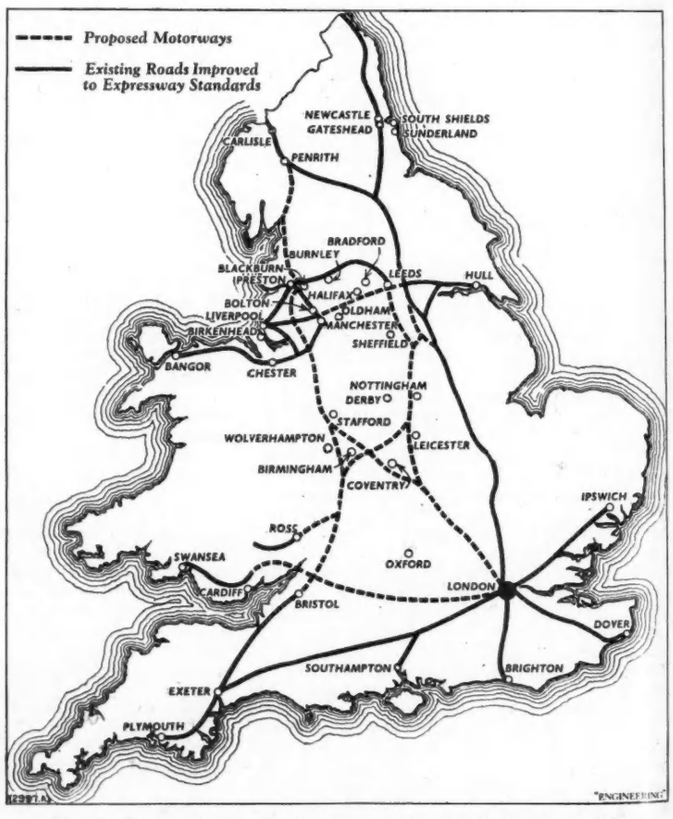

Fig. 1 Proposed network of express routes for England and Wales.

* Paper read before Section G of the British Association at Bristol on Monday, September 5, 1955.

† Department of Civil Engineering, University of Liverpool.

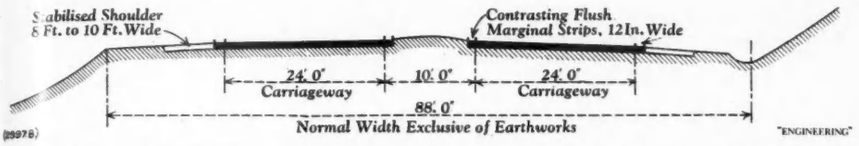

Fig. 2 Cross-section of proposed four-lane motorway, that is, a road built for certain classes of traffic and to which undesirable vehicles can be denied access.

essential feature of design that to achieve uninterrupted high traffic flows the road must allow all traffic to maintain the stream speed. This should lie in the 30–55 m.p.h. range and preferably in the range 40–55 m.p.h. as this is nearer the desired speed of most drivers. This result is best achieved by ensuring that the road is most comfortably travelled at these speeds and is also completely safe, that all vehicles have a sufficient power to weight ratio, and that full use is made of the carriageway.

The appearance and design standards of the motorways will depend on these four points. Basically the art of expressway design is to induce drivers to travel at speeds decided by the designer, while the road remains safe at higher or lower speeds. This can be done very satisfactorily by taking a stream speed, say 50 m.p.h., as the design speed and fully designing the road for this speed. This means that at this speed superelevation will completely balance centrifugal forces, and transition curves will occupy a suitably short travel time to allow for the steering movement and for a reasonable rate of application of the superelevation. A safe stopping sight distance appropriate to 50 m.p.h. will be provided everywhere. Access and egress to and from the through lanes should also be made completely safe at this speed. Higher speeds may be used with reasonable safety over most of the road at the sacrifice of some comfort. At all speeds other than the design speed tyre friction will be required to resist some of the centrifugal force on curves, so that at 70 m.p.h. about half the force is resisted by tyre friction as in the design figures recommended by the Ministry for ordinary roads. Where only the minimum sight distance appropriate to the design speed has been attained on curves or summits, safety will demand a reduction of speed when in excess of 50 m.p.h.

A further point in favour of full design based on stream speed is that all the curves are equally safe for all road surface conditions at the stream speed. At that speed no tyre friction is required, the progressive change in surface characteristics will not affect the safety of vehicles and the safest speed when the road is covered by ice or snow will still be the design speed. A safe stopping sight distance appropriate to the design speed must be provided everywhere on the road; for divided carriageway roads this will be the distance required to bring a vehicle to rest from the design speed and will be based on a perception plus reaction period followed by a braking distance. A reasonable standard of braking efficiency must be expected of vehicles. This can best be ensured by an annual mechanical inspection and test which could be required before the issue of a road licence, or a commercial licence, and would be especially necessary before commercial vehicles could be allowed to exceed the present statutory 20 or 30 m.p.h. speed limit and would almost certainly require these vehicles to be fitted with servo braking systems to give a retardation of at least 0·5 *g*.

The safe stopping distance recommended by the Ministry for dual-carriageways (350 ft. at 50 m.p.h.) can be achieved within the carriageway limits on the sharpest motorway curvature (2 deg.) for the usual driving position. A summit vertical curve between two of the steepest inclines will require to be at least 300 ft. long to maintain the same sight distance over the top. The 650 ft. stopping distance recommended for a speed of 70 m.p.h. comes within the 15 ft. wide side verges of the motorway but would require the summit curve connecting 1 in 30 inclines to be 1,000 ft. long.

It is essential to the successful operation of motorways that vehicles using the facility have an adequate power/laden weight ratio to be able to traverse the road at the stream speed. This consideration arises mainly in the case of commercial vehicles and cars of low brake horsepower, and while there is little that can be done about the heavily laden baby car, commerical vehicles must be licensed to carry only such loads as will ensure that a certain maximum laden weight/power ratio is not exceeded. Operators of commercial vehicles and their drivers should be made to understand the importance of compliance with this requirement. Manufacturers of commercial vehicles are generally progressive and would no doubt soon develop vehicles to operate with the required power ratio at speeds in the 40 to 50 m.p.h. range with corresponding braking once the requirements are stated. An adequate power/weight ratio is required to climb inclines of the steepest probable gradient (1 in 30) without an appreciable fall in speed, and certainly without a gear change. Adequate power is also required for acceleration at junctions, to reach the stream speed from link roads in a short distance. It is possible that in a few places on the proposed motorways and express routes gradients exceeding 1 in 30 will occur. At these locations much of the traffic, especially commercial vehicles, will find it necessary to reduce speed quite considerably, especially if a gear change is necessary. Congestion may result if traffic flows are heavy and although this is not too serious on a divided road it may be considered worth while adding an additional lane for slow ascending traffic. This will be carried over the summit to enable vehicles to accelerate up to the stream speed before the road reduces in width to two lanes again.

The full utilisation of the carriageway can be justified on both economic grounds and also to ensure greater safety. The first and most important consideration is that there must be no obstruction to traffic travelling in a lane at the stream speed, either by stationary or slow moving vehicles. As has already been said, it is desirable that as much traffic as possible should move at the stream speed, but it is more important that vehicles should not travel at speeds below the required stream speed, as the speed of a stream of vehicles is normally determined by the slowest vehicle on the road. For this reason legislation is necessary to allow vehicles to travel at speeds in excess of the present legal limit on special roads if they are properly equipped to do so.

The stationary vehicle is a very serious problem in road usage, and although less frequent in rural areas than in towns it is much more dangerous on the high-speed rural road. The presence of one standing vehicle deprives traffic of the use of one traffic lane for a great distance and causes a great hazard by forcing vehicles to change lane.

It is probable that stopping on the carriageway of a special road, except for traffic conditions or in an emergency, will be made an offence, so provision must be made for vehicles to draw off the carriageway in the event of a breakdown or to allow drivers to rest. This latter provision can be met by constructing lay-bys at frequent intervals, but the former is so important to safety that the motorways will be considered complete only when a continuous hard standing has been built alongside the carriageway. Lanes will be 12 ft. wide on the motorways compared with 11 ft. on most of the existing divided carriageways and the apparent width will be increased by the absence of upstanding kerbs. These on our existing roads reduce the effective width of a traffic lane by about 2 ft. when more than an inch or two in height. They will be replaced by flush marginal strips 12 in. wide on the new roads, which will be "reflectorised" and given a surface texture to contrast with that of the carriageway. The effective width of a traffic lane can also be reduced by "lateral obstructions" in the form of conspicuous objects on the side verges, which have an effect on drivers when within about 6 ft. of the edge of the carriageway. The motorways will have 15 ft. wide side verges which will normally be free from obstructions. Lay-bys, where constructed, should be well away from the carriageway so that vehicles using them will not obstruct sight lines, and hard shoulders must be of adequate width to allow vehicles to stand well clear of the carriageway.

So we arrive at a picture of the motorways, shown in section in Fig. 2. They will normally have a width of 88 ft. between boundaries and provide two carriageways each having two 12 ft. wide lanes divided by a central reservation 10 ft. wide. A contrasting flush marginal strip will line both sides of each carriageway and a stabilised shoulder 8 to 10 ft. wide will form part of the 15 ft. wide side verges. Maximum curvature, 2 deg.; normal maximum gradient, 1 in 30; minimum sight distance, 350 ft., 650 ft. preferred; maximum crossfall, 1 in 12·5. Super-elevation and transition length will be based on the design speed of 40 to 50 m.p.h. using a constant value throughout for the coefficient of radial acceleration. There will be no gullies, except perhaps on super-elevated curves, drainage will be off the edge of the shoulder into soakaways. The edges of the carriageway will be indicated by the flush marginal strips which will contrast with the carriageway in both colour and surface texture;

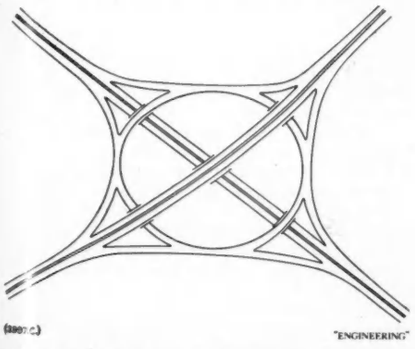

Fig 3 Two-level roundabout at intersection of motorways or expressways.

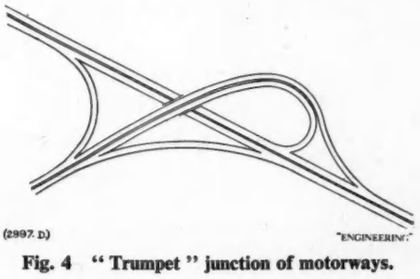

Fig. 4 "Trumpet" junction of motorways.

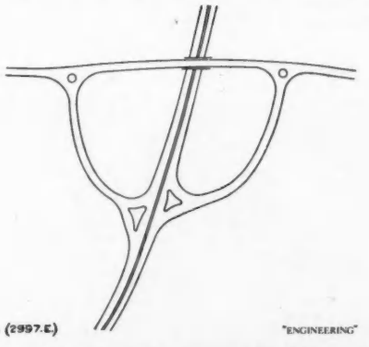

Fig. 5 Double-sided access point from underpassed local road.

they may in fact be ribbed transversely so that drivers will receive an audible warning that they are running along the edge of the road. A method coming into general use in America to prevent drivers missing the edge of the carriageway, especially in fog and at night, is to lay a white line made to reflect by the inclusion of small glass spheres (*ballotini*) about 18 in. from the edge of the carriageway. In this position occasional vehicles will run over the line so keeping the glass spheres clean. This type of road marking has been found to keep traffic in lane better, to reduce high speeds by day and increase those at night, resulting in similar speeds at all times of day.

It is possible to make an estimate of the future traffic demand for an expressway facility at some date approximating to the life of the proposed road. This must be based on the existing flow pattern and an estimate of the regrouping which would follow the establishment of an expressway. Account must also be taken of the growth in traffic, both of private and of commercial vehicles, of new planning proposals and of social changes. Generally the figure is found to be within the capacity of a four-lane divided road, which may be taken to be about 1,000 vehicles an hour in either direction at the operating speeds envisaged, allowing for a reasonable amount of freedom for overtaking and choice of a speed above that of the majority of traffic. Traffic flows in excess of this figure could be carried on occasions if all traffic were to move at the same speed with no overtaking, but such conditions would be intolerable if they were to persist. Over a part of the proposed motorway system in industrial areas, traffic flows are expected to require the provision of a six-lane divided road which will provide for a much greater flow.

JUNCTIONS

One of the most important features of the motorway and expressway system will be the junctions. These must be able to deal effectively with the full flow of traffic entering the junction so that no congestion is caused which might spread back to affect a great distance along the motorway. This requirement can only be met for high-speed roads by eliminating crossing movements of opposing streams of traffic and by the segregation of fast moving through traffic from the slower traffic entering or leaving the through lanes and also by spacing junctions several miles apart. Grade separation works are necessary for all right-turning movements, as are accelerating and decelerating lanes from link roads to the through lanes. The junctions as planned for the motorway system will fall into two distinct types. First are the major junctions of which there will be comparatively few, to be found where motorways join or cross, or where major link roads connect with important centres of population. In this type of junction each road will be of similar importance and will require that the through lanes of each keep to a high-speed alignment. The three-level roundabout system (Fig. 3) is the most likely solution where two roads cross, and the "trumpet" layout (Fig. 4) for joining roads. The second type of junction will be found more frequently on the motorway system and will form the minor access points. Where traffic is likely to be heavy, a two-level roundabout may be necessary but in most cases a fairly simple arrangement of two-way link roads can be made to connect the motorway with the minor road which it will over or under pass (Fig. 5). The number of these minor junctions must be kept to a minimum in the interests of safety, preferably at a spacing of 5 to 10 miles, but it follows that their frequency must increase around centres of population. Consequently there will be parts of the motorway where junctions occur at quite close spacings, perhaps four junctions in ten miles, and the number of grade separation works to over or underpass local roads will be especially numerous in these same areas. Fig. 6, reproduced by permission of the British Road Federation, shows the junction of two motorways where the Mannheim spur joins the main *Autobahn* between Frankfurt and Stuttgart in Western Germany.

At the intersection of less heavily trafficked expressways and especially in built-up areas single level junctions may be used, in the form of large traffic rotaries. The central island will be very much larger than that of the familiar roundabout and not circular, and could very well be laid out as a garden square, as in the centre of Coventry. The main feature of this type of junction will be the weaving areas where traffic from one stream crosses that of another. This will require the weaving area to have a width at least equal to the combined widths of the entering carriageways and a length dependent upon the number of crossing movements expected. Over the weaving area the carriageway should be sensibly straight to ensure that full use will be made of the carriageway and allow drivers to weave between traffic of the meeting stream at relatively high speeds.

CONTINENTAL MOTOR ROADS

Motor roads are now common features of Continental European road systems and most of the Continental countries are engaged on extensive motor-road construction programmes. *Autostrada* were built first in Italy in the early 1920's. Germany started construction of motor roads in the 1930's and has completed about 2,500 miles of the projected 6,000 miles, and as a result has probably the best main road system in Europe. This has contributed very greatly to the rapid economic recovery in Germany since the war. France, with its *Autoroutes de l'Ouest and du Sud*, Belgium, Holland and Sweden all have motorways in use or under construction. A study of the roads of the countries with the longest experience of the design of motor roads reveals several features of interest to designers. The Italian roads were built as very high speed toll roads not directly useful to the country's economy. Few were built and in the later years before 1939, most of the Italian road making was in connection with the colonisation of North Africa. Since the war many new *autostrada* have been planned and are being constructed as an economic necessity to advance the tourist trade so important to Italy.

The German *Autobahnen* offer most lessons in design as development there has been continuous for about 25 years. The main faults of the earlier roads, apart from structural defects, have been the poor alignment and the narrowness of the stabilised shoulder (*bankette*) along the nearside of the carriageways. Some of the first stretches of road were built with long straights connected by curves of near the minimum radius, little use being made of curves of long radius. These roads have had a fairly high accident rate attributed to their layout and German road engineers now recommend that new roads should be constructed using a better combination of curvature, generally of long radius. The poor appearance and optical illusions resulting from certain combinations of vertical and horizontal curvature were features of these earlier roads which followed the application of geometric planning and minimum standards to the natural landscape. On new work a perspective drawing is constructed to examine the effect of combined horizontal and vertical curvature. The narrow *bankettes* were also a cause of accidents. On earlier construction they fulfilled the dual purpose of adding to the apparent width of the carriageway and marking its limits, while during construction they were laid first to serve as a bed for the track carrying the constructional machinery. As such, they were made one metre wide with the result that vehicles stopped partly on the carriageway. This dangerous situation has been avoided in later construction by making the *bankettes* 2·25 metres wide and on some of the older roads an additional strip is being laid to increase the width of the original *bankettes* to this amount. Definite design standards are laid down for the *Autobahnen* based on maximum speeds of 100 m.p.h. in lowland country. Later specifications show a trend towards a more easily traversed road to allow for the greatly increased numbers of commercial vehicles using these roads, and a lower assumed maximum speed.

OPERATION OF MOTORWAYS

Introducing of motorways and expressways to this country will give rise to a number of problems new to road administrators. One will concern the provision of services for the motorist, such as fuel and repairs, and parking places where drivers may halt for a rest and refreshment. The sites for these services will be strictly controlled and following the German example they will probably be incorporated into the road layout at access points. The German filling stations are built to standard patterns by a fuel monopoly, but we, as a race of individualists, will, I hope, manage to avoid this. There will be opportunities in the landscaping of major junctions for the inclusion of transport cafés, restaurants and perhaps even motels, with plenty of parking space available away from the road. The rotary type of junction lends itself particularly well to the provision of motorists' amenities as traffic may enter or leave the parking ground from the circular road with least confusion and no interference with through traffic. There one set of buildings would serve traffic from all directions whereas at minor access points a filling station would be required at each side of the road to serve both directions.

The high speed nature of the roads will require something new in signposting, particularly as all turns off the main road will be to the left regardless of the direction of destination. Large characters on a contrasting coloured ground will be required, with a minimum of wording, for advance warnings placed up to half a mile before the turn. Large cartoon-map signs will also be useful, particularly at the approaches to major junctions to show the position of the towns by which the motorway is passing.

A problem for which a solution will be more difficult is that of the disabled vehicle on the carriageway. Safety will demand that the driver of such a vehicle should get it off the carriageway at all costs. Toll-road operators have had much experience of dealing with this type of emergency. In this country the Mersey Tunnel managers have to remove several disabled vehicles from the two-mile tunnel on most days. They have developed a system of policing the tunnel, which constitutes an expressway in fact, so that a breakdown vehicle may be called up by radio to remove any obstruction in the shortest possible time. Such a system is quite applicable

Fig. 6 Junction of Mannheim Spur and Frankfurt-Stuttgart Autobahn in Western Germany.

to motorways, with radio patrols operated by a special motorway police force or by the joint motoring organisations. Roadside telephones direct to the nearest service station could also assist in the event of accident.

New standards of road use and stricter attention to good driving manners will be required due to the higher speeds on the motorways and expressways. Education in the proper use of expressways and the return obligations required of drivers using them may be necessary. Drivers should realise the necessity for compliance with certain rules of expressway use, including the necessity of keeping up to the stream speed, of not exceeding a certain laden weight/power ratio and, probably most important of all, of not stopping on the carriageway.

MOTORWAYS FOR BRITAIN

Much has been written since the war urging the immediate construction of special-purpose motor roads, both in the technical and the national Press. It has been made clear that no densely-populated country can afford to do without motorways and express routes, both on economic and humanitarian grounds. At present over 70 per cent. of our goods tonnage is moved by road transport, and the figure is increasing, particularly for short hauls. It is only for bulk freight and long hauls that rail can compete economically with road transport. And this is with artificially high costs for road haulage caused by the high fuel tax, road tax and the use of vehicles which must be designed to operate under unfavourable road and traffic conditions. These conditions give rise to time wastage costing many millions of pounds annually when taken over the trunk roads of the country, and the fuel consumption of vehicles could be reduced by 20 to 30 per cent. if they were to be operated over motorways. The daily life in towns and cities affected by trunk road paralysis has already become intolerable and is seriously threatening commerce, costing the communities affected incalculable millions in lost time.

Most of the counties through which the proposed motorways will pass are actively preparing plans and some of the first parts of the North-South motorway which will be constructed will be in Lancashire, where the need for increased communications is extremely acute. The present main trunk route, A.6, London to the north and Scotland, lies through the centre of industrial Lancashire. Of its 63 miles in the county, 30 have a speed restriction, there are over 500 intersections, 20 sets of traffic lights, four low bridges and three level crossings. In contrast, there will be about 15 junctions all of the grade-separation type in the 58½ miles of the North-South motorway in Lancashire. It is estimated that the effect of the motorway facility will be to reduce the journey time through the county from about 2½ hours at present to about 70 minutes so saving perhaps £1,000,000 a year in time value alone. Four million people live in Lancashire within 12 miles of the proposed motorway. They are depending upon it to open up congested areas and to allow normal life to return to towns along the trunk routes, with a saving of perhaps 500 casualties a year.

The way ahead has been shown by Germany, France and America and is clearly that it is not worth while converting old roads to main highways. Future traffic needs must be met by constructing new motor roads, which are being built with all speed in almost every country as an economic necessity. Since we in this country have lost so much leeway in our road building we must now apply ourselves to making good our deficiencies, at the same time profiting from the experience of others. If built now a motorway will cost us about £250,000 a mile and the establishment at the earliest possible moment of a central motorway authority with powers to raise the £200 million required for the complete scheme would be a most laudable act of any government, for the scheme is essentially a whole and each motorway must of necessity be built complete as one undertaking.

See Weekly Survey for editorial comment.

SOIL MECHANICS ASPECTS OF THE DESIGN OF FOUNDATIONS*

(1) BEARING CAPACITIES AND SETTLEMENT

By F. D. C. Henry, B.SC., A.M.I.C.E., A.M.I.STRUCT.E., F.G.S.†

The present position and the possible future trend of soil mechanics investigations in relation to the design of pad, strip and raft foundations located on the surface of the ground or at a relatively shallow depth are discussed in this paper. These investigations can be considered under the four headings: (a) *bearing capacity of the soil,* (b) *settlement of the foundation,* (c) *bearing pressure distribution at the soil/foundation contact surface, and* (d) *constructional problems due to the nature of the soil. Headings* (a) *and* (b) *are discussed in the first part of the paper published below. The subject of heading* (c), *bearing pressure distribution, will be discussed in part two of this article to be published subsequently. Constructional problems* (d) *are met by special excavation techniques or by geotechnical processes. Thus, for example, excavation can be carried down several feet at a time in stiff clay before each set of timbering is inserted, whereas in loose sand it is necessary to drive down vertical timber sheeting as excavation proceeds. If sand is water-bearing then well-point pumping, cementation or other geotechnical process must be employed to keep the excavation dry. These problems are so varied that it is impossible to discuss them further herein. There are several special features which must be taken into account in the design of continuous or strip footings and raft foundations and these will be outlined in the second article.*

BEARING CAPACITY OF THE SOIL

The ultimate bearing capacity of the soil is defined as that value of the net loading intensity at which the soil fails in shear. The net loading intensity p_n is the amount by which the pressure on any horizon in the soil due to the weight of the structure less excavation plus filling exceeds the original overburden pressure. The maximum safe bearing capacity p_s is the maximum intensity of loading that the soil will carry without risk of shear failure. The allowable pressure p_a is the maximum allowable net loading intensity determined either from considerations of shear failure, in which case $p_a = p_s$, or from considerations of settlement, whichever is the lesser. On sands and gravels the settlement criterion determines the allowable pressure for all footings except those a few feet in width, but on silts and clays both shear failure and settlement must be considered.

The methods due to Fellenius, Krey and others, of calculating bearing capacity of clays were based on assumed rupture or slip surfaces of circular, logarithmic spiral or other form, as indicated in Fig. 1 (*a*). For stability in the case of a circular slip surface, the moment of the load P on a continuous foundation about the circle centre must not be greater than the moment about that point of the weight of soil W within the slip surface and of the shearing resistance of the soil along the slip surface. Wilson[28] (1941) assumed a slip surface conforming to a circular arc and derived the equation

$$p_u = 5{\cdot}5c\left(1 + 0{\cdot}38\frac{d}{b}\right) \quad . \quad . \quad (1)$$

for the ultimate net bearing capacity of a strip footing of width b founded at a depth d in clay with an assumed value of zero for the angle of shearing resistance ϕ of the soil. In order to simplify the analysis it is assumed that no soil is displaced by the footing and consequently the soil contained within the arc of the slip surface is balanced and does not contribute to the stabilising moment. The moment of the foundation load P about the slip surface centre is thus balanced solely by the shearing resistance along the slip surface. Consequently, the ultimate bearing capacity is the calculated value of p_u augmented by the pressure equal to that of the displaced soil. Equation (1) was derived for cases where $d < 1{\cdot}5$.

The method of calculating bearing capacity which is more commonly employed to-day is based on a different mode of failure. The original theory was due to Prandtl and this has been modified and extended by Terzaghi and others. The mode of failure of the soil beneath a continuous or strip footing with a rough base on the surface 1 of the ground is as follows (Fig. 1 (*b*)). The soil in zone I is in a state of elastic equilibrium, and the tendency for lateral spreading to take place is resisted by friction at the soil/footing contact surface. Shearing occurs throughout the whole of zones II but, although a state of passive plastic equilibrium theoretically exists in zones III, in practice the lateral compression is insufficient to induce this state completely, and the zones are wholly or partly in a state of elastic equilibrium. At failure the horizontal surfaces of zones III are lifted proud of the general ground surface. Terzaghi (1943) assumes that in the case of a footing

* Paper read at a Joint Meeting of Sections C and G of the British Association at Bristol on Monday, September 5, 1955.

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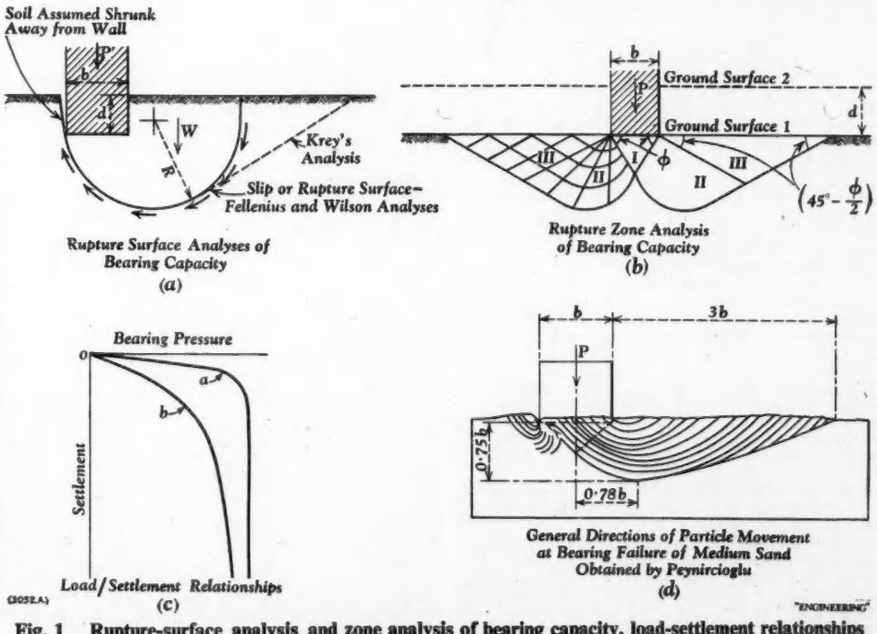


Fig. 1 Rupture-surface analysis and zone analysis of bearing capacity, load-settlement relationships and directions of particle movement at bearing failure.

located at a relatively shallow depth d—say not exceeding the width of the footing—below the ground surface 2, the soil above the plane of the base of the footing can be treated with sufficient accuracy as a surcharge equal to γd, where γ is the density of the soil. If the footing is located at a depth of the order of $5b$ or more, the failure surface of zones III curve upwards and backwards to meet the shaft of the footing.

If the properties of the soil are such that the strain which precedes failure of the soil by plastic flow is small, appreciable settlement of the footing does not occur until a state of plastic equilibrium is reached in the soil beneath the footing (curve *a*, Fig. 1 (*c*)). In this case the entire mass of soil on each side of the footing up to ground surface is in a state of plastic equilibrium and the condition is known as a general shear failure. If the properties of the soil are such that the strain which precedes failure by plastic flow is large, appreciable settlement occurs before failure spreads to the surface (curve *b*, Fig. 1 (*c*)). This condition is known as a local shear failure and the critical load is taken as that at which the slope of the settlement curve increases conspicuously.

From these considerations Terzaghi[17] (1943) derived mathematically the equation

$$p_u = c\,N_c + \gamma\, d N_q + 0{\cdot}5\,\gamma\, b N_\gamma \quad . \quad (2)$$

for the ultimate gross bearing capacity of a strip footing based on general shear failure, where N_c, N_q and N_γ are bearing capacity factors depending only on the value of ϕ. The values of these factors have been computed and can be determined readily from charts. From an examination of experimental evidence Terzaghi concluded that the ultimate gross bearing capacity, based on general shear failure, of a square footing is

$$p_u = 1{\cdot}3\,cN_c + \gamma\, d N_q + 0{\cdot}4\,\gamma\, b\, N_\gamma \quad . \quad (3)$$

If the soil is soft or loose, appreciable settlement occurs before the state of plastic equilibrium extends to zones III and this represents the case of local failure. An approximate estimate of bearing capacity is given by assuming that the cohesion is reduced to $\frac{2}{3}c$ and that the internal friction is $\frac{2}{3}\tan\phi$. Then for a strip footing

$$p_u = 0{\cdot}67\,c\,N'_c + \gamma\, d N'_q + 0{\cdot}5\,\gamma\, b\, N'_\gamma \quad (4)$$

and for a square footing

$$p_u = 0{\cdot}87\,c\,N'_c + \gamma\, d N'_q + 0{\cdot}4\,\gamma\, b\, N'_\gamma \quad (5)$$

where N'_c, N'_q snd N'_γ are reduced factors based on $\tan\phi$.

If cohesion is absent in sand, the first term in the above four equations is zero and (2) and (3) become

$$p_u = \gamma\, d N_q + 0{\cdot}5\gamma\, b\, N_\gamma \quad . \quad . \quad (6)$$

and

$$p_u = \gamma\, d N_q + 0{\cdot}4\gamma\, b\, N_\gamma \quad . \quad . \quad (7)$$

Both N_q and N_γ increase rapidly with increase in ϕ. It will be seen that the bearing capacity increases linearly with both founding depth and breadth of footing. If the water table is at or above the base of the footing the bearing capacity is reduced by about 50 per cent. since the effective unit weight of the sand γ is reduced to its submerged weight.

In the case of clay, if ϕ is assumed zero, N_q is unity, N_γ is zero and N_c is 5·7. Hence equations (2) and (3) become

$$p_u = 5{\cdot}7c + \gamma\, d \quad . \quad . \quad (8)$$

and

$$p_u = 7{\cdot}4c + \gamma\, d \quad . \quad . \quad (9)$$

It will be seen that bearing capacity on clay is independent of the width of the footing. Skempton[18] (1951), has studied the bearing capacity of clays ($\phi = 0$) in the light of theoretical and experimental evidence and has derived values for N_c which increase with increase in the depth of the foundation below the surface but reach constant values of 7·5 and 9·0 for strip and square footings respectively at $d = 4b$. Thus the effect of the shearing resistance of the soil above the level of the base of the footing is taken into account but it should be noted that the respective values are 5·1 and 6·2 for $d = 0$ and are less than the Terzaghi values. The rupture surface analyses (Fellenius, Krey) and the rupture zone analyses (Prandtl, Terzaghi) are fundamentally different and it is of interest to examine the laboratory and field evidence supporting them. The following are representative of the more recent experimental investigations.

RECENT EXPERIMENTAL INVESTIGATIONS

Golder (1941) carried out tests on axially-loaded model footings ranging in size from 6 in. × 6 in. to 30 in. × 6 in. on the surface of clean dry river sand contained in a 3 ft. 6 in. × 3 ft. 6 in. × 14 in. deep box. Tests were also carried out on footings ranging from 3 in. × 3 in. to 18 in. × 3 in. on remoulded London clay in a 2 ft. 6 in. × 1 ft. 8 in. × 8 in. deep box.

Peynircioglu[10] (1948) tested a series of axially loaded footings 10 in. × 3 in. on the surface of coarse and fine sands contained in a 22 in. × 10 in. × 13 in. deep box with glass sides. The depth of the sand beneath the footing was about 8 in. and the tests were made with the sand surface both horizontal and inclined. The movement of the sand grains was recorded by time-exposure photographs. Experiments were also carried out on square and semi-circular footings.

Meyerhof[7, 8, 9] (1948, 1951, 1953) has reported the results of tests on axially-loaded footings $\frac{1}{2}$ in. to 6 in. long × $\frac{1}{2}$ in. wide and 1 in. to 3 in. long × 1 in. wide on the surface of, and at depths up to 6 in. in, clean dry medium river sand contained in a tank 18 in. × 15 in. × 18 in. deep. Some tests were made on footings on sand contained in a box with a glass front; the inside of the glass was smoked so that the movements of the grains under load were automatically scribed on the glass. In another series of tests on footings of various lengths and 1 in. wide on the surface of, and at shallow depths in, loose and dense medium Ham River sand and remoulded London clay the load was applied vertically and at eccentricities up to $0{\cdot}4b$. This was followed by similar tests on the surface of sandy soil in which the load was applied centrally and at angles of inclination from the vertical ranging between 0 deg. and 50 deg.

Eastwood[2, 3] (1951, 1955) made tests on axially-loaded footings 6 in. to 30 in. long and 3, 4 and 6 in. wide on the surface of dry and inundated sand contained in a box 4 ft. × 3 ft. 6 in. × 16 in. deep. Other tests were carried out on eccentrically loaded footings 6, 8 and 10 in. wide on the surface of dry sand contained in a 10 ft. × 5 ft. × 3 ft. box; eccentricity of loading was varied from zero to nearly $\frac{b}{4}$.

The modes of failure of axially-loaded footings on sand obtained by these investigators are as follows. Golder obtained symmetrical failures in which the sand rose all round the footings. Meyerhof reports that failure rarely took place with the formation of two rupture zones but generally the footing tilted slightly to one side, on which a small crater was produced, with a single failure zone on the other side of the footing. Peynircioglu found that in nearly all cases with strip footings the rupture zone developed fully on one side but only partly on the other (Fig. 1 (*d*)). With square and circular footings the rupture zones were symmetrical. On both dry and inundated sand Eastwood obtained symmetrical failure with square footings but asymmetrical failure with rectangular footings. In this latter case the footings initially sank vertically but at ultimate loads slight lateral movement was observed. Golder[5] employed a hydraulic jack to load the footing whereas Peynircioglu and Eastwood used a single-screw jack and undoubtedly the hydraulic jack enables a steady and more uniformly distributed load to be applied than a screw jack. It can be concluded that given ideal loading conditions the symmetrical type of rupture zone failure is obtainable in the laboratory. Slight eccentricity of loading or variation in the mechanical properties of the soil is probably responsible for the asymmetrical type of failure. None of the experimenters reported rotational effects in failures; neither did they interpret their results as rupture surface failures.

In the symmetrical failures obtained in Golder's tests the zone of rupture broke the surface at a distance of about three times the width of the footing from the footing whereas in the asymmetrical failures obtained in Eastwood's tests the distance was about four times the width when the footing was unrestrained laterally and equal to one to three times the width when the footing was restrained. It has been suggested that the discrepancy may be due to confinement of the sand in Golder's work but evidence indicates that this is unlikely. Fig. 1 (*b*) shows that the distance depends on the value of ϕ and this is one obvious reason for differences in observed values.

The Fellenius and Wilson solutions are based on the assumption of a symmetrical cylindrical slip surface. In Krey's method it is assumed that the slip surface is partly cylindrical and that the wedge of soil contained above the sloping tangent to the curve (Fig. 1 (*a*)) is thrown into a state of passive plastic equilibrium. Both theory and experiment show that shearing failure in the soil can be expected to develop first in zones near the edges of the foundation but this state of affairs does not constitute a stress condition in the rupture surface methods. Furthermore, although in the Krey solution it is assumed that passive resistance will be developed in an extreme triangular zone, experimental and field evidence indicates that such resistance is unlikely to be fully developed in this region. It seems that the actual mode of failure is satisfied better by the assumption of rupture zones than by the assumption of a rupture surface, although the true solution is likely to be composite, with rupture zones adjacent to the footing and a rupture surface breaking ground level. The kinematics of the problem as one of rotation require a perfectly cylindrical rupture surface and this rarely, if ever, appears to be attained. Excluding the considerations discussed above, an advantage of the rupture surface methods is that they are well adapted to graphical solutions where the shearing strength of the soil varies. On the other hand, the advantage of the rupture zone analyses is that they are more readily applied.

Several other conclusions derived from these experiments are worth recording here. Golder found that the ultimate bearing capacity of an axially-loaded square footing on the surface of clay was approximately 30 per cent. greater than that of a continuous or strip footing of equal width and this effect is confirmed by Meyerhof who quotes an increase of about 20 per cent. Meyerhof's tests also revealed that the ultimate bearing capacity of an axially-loaded square footing on the surface of sand was 30 per cent. less than that of a strip footing, thus confirming, within practical limits, the 20 per cent. reduction employed by Terzaghi which is apparent in equations (6) and (7) with $d = 0$.

It is generally accepted that the bearing capacity of sand inundated to the underside of a footing is about 50 per cent. of the capacity of dry sand because the submerged unit weight of the sand is only about one-half of its dry weight. Eastwood's experiments indicated that the inundated capacity was 80 per cent. of the dry capacity but in the discussion on this work Meyerhof quoted his own tests and also American work which confirmed a capacity of 50 to 60 per cent. and Golder quoted tests which also confirmed these values.

BEARING CAPACITY CALCULATIONS

The following is a typical example of bearing capacity calculations, in this case for an actual failure which was originally analysed by Skempton[12] (1942). The 9 ft. × 8 ft. footing was founded at a depth of 5·5 ft. in clay at Kippen, Scotland. The shear strength of the soil near the surface was 1,200 lb. per square foot, but at and below the footing base it was 350 lb. per square foot. The settlement of the footing developed during the process of failure was about 10 in. The load on the clay beneath the footing was estimated to lie between the limits of 105 tons and 85 tons and was most probably about 100 tons; this leads to a gross pressure of 3,100 lb. per square foot. It is interesting to recalculate this problem using the equations derived by Terzaghi, Wilson, Meyerhof and Skempton. The density of the clay above the level of the base of the footing was about 110 lb. per cubic foot and substituting in equation (9)

$$p_u = 7{\cdot}4 \times 350 + 5{\cdot}5 \times 110$$
$$= 3{,}260 \text{ lb. per square foot.}$$

This compares favourably with the actual value.

The ultimate net bearing capacity given by equation (1) for a continuous footing is

$$p_u = 5{\cdot}5 \times 350\left(1 + \frac{0{\cdot}38 \times 5{\cdot}5}{8}\right)$$
$$= 2{,}430 \text{ lb. per square foot.}$$

Allowing an increase of 30 per cent. for the square shape of the footing, $p_u = 3{,}160$ lb. per square foot. To this must be added the pressure due to the weight of the earth displaced by the footing, say 600 lb. per square foot, and then $p_u = 3{,}760$ lb. per square foot. This is rather optimistic. For a square footing at ground level the Terzaghi equation (9) gives a slightly higher capacity than the Wilson equation (1).

Wilson[20] (1941) found that Krey's method gives reasonable values of bearing capacity for surface footings and that the values increase with foundation depth up to $d = 0{\cdot}4b$, beyond which they decrease to values less than that for a surface footing. Skempton (1942) found that the Krey method gave a capacity of (2,100 + 600) = 2,700 lb. per square foot for the Kippen footing. Meyerhof (1951) took into account the shearing resistance of the soil above the level of the base and gives the equation, $p_u = c\left(1 + 0{\cdot}15\,\frac{b}{l}\right)N_{cq} + K_s\gamma d$ for the bearing capacity of a rectangular footing on cohesive soil. The factor N_{cq} depends on the ratio $\frac{b}{l}$ and the roughness of the foundation shaft and K_s is taken as unity. In this example the bearing capacity should lie between

$$p_u = 350\left(1 + \frac{0{\cdot}15 \times 8}{9}\right)8{\cdot}5 + 5{\cdot}5 \times 110$$
$$= 3{,}950 \text{ lb. per square foot}$$

for the case of a rough shaft of the full length and breadth of the footing continuous up to ground level and

$$p_u = 350\left(1 + \frac{0{\cdot}15 \times 8}{9}\right)6{\cdot}6 + 5{\cdot}5 \times 110$$
$$= 3{,}200 \text{ lb. per square foot,}$$

for the case of a smooth shaft when the adhesion

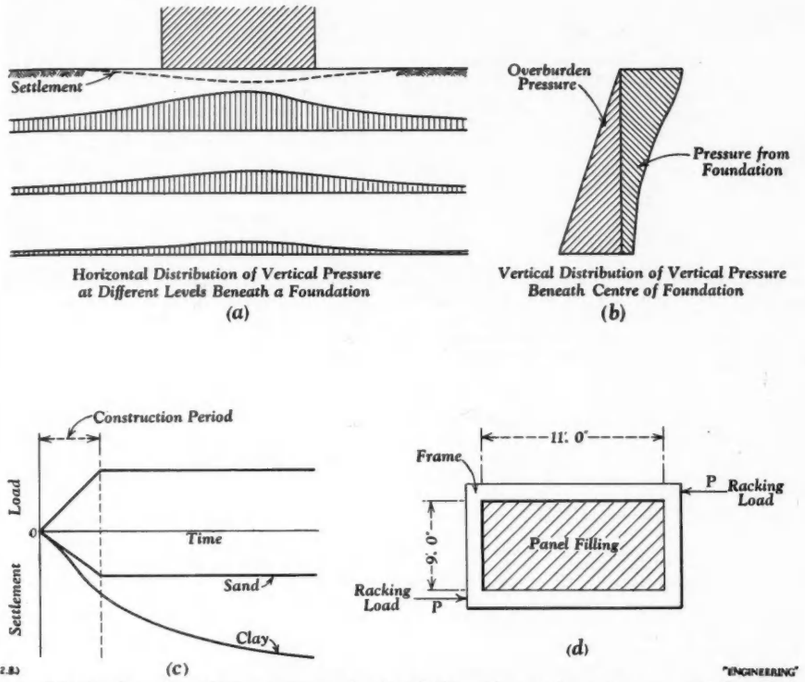


Fig. 2 Distribution of vertical pressure under foundations, time-settlement curves, and the effect of panel filling on the rigidity of frames.

between soil and shaft is zero. Since the thickness of the footing concrete was only about 2·5 ft., with 3 ft. of hardcore filling to ground surface, it is reasonable to accept a value for bearing capacity, as given by this theory, of 3,500 lb. per square foot; a value which is higher than the actual pressure at failure.

Skempton (1951) derived a value of $N_c = 7{\cdot}2$ for a ratio of depth to breadth of 0·7 and then

$$p_u = 7{\cdot}2 \times 350 + 5{\cdot}5 \times 110$$
$$= 3{,}100 \text{ lb. per square foot.}$$

This corresponds exactly with the actual bearing pressure at failure but it was estimated that adhesion between soil and footing sides would increase the capacity by about 450 lb. per square foot, thus bringing p_u to 3,550 lb. per square foot.

SETTLEMENT OF THE FOUNDATION

When a vertical pressure is applied to a mass of soil, the settlement which ensues comprises an immediate settlement and a delayed or consolidation settlement. The immediate settlement is due to elastic deformations which are completely reversible on removal of the load and to plastic deformations which are irreversible. Consolidation settlement takes place over a period of time after the load is applied in zones which are completely saturated. In saturated zones, part of the applied load is carried initially by the pore water under hydrodynamic excess pressure and the consolidation process involves expulsion of water from the pores. As the excess pressure gradually falls to zero, the load is transferred to the solid particles and the resulting deformations are both elastic and plastic. Plastic deformations may involve some lateral migration of particles. An estimate of settlement comprises the magnitude of ultimate settlement and the rate of increase of settlement.

Uniform settlement of an entire structure may lead only to damage to services, but differential settlement may lead also to damage to the superstructure. Obviously, both maximum and differential settlement must be limited to acceptable values and hence—as mentioned earlier in this paper—the allowable pressure beneath a foundation may be governed by considerations of either shear failure or settlement.

ALLOWABLE PRESSURES ON SANDS AND GRAVELS

The allowable pressure on sands and gravels s controlled by the settlement criterion, except where the footing is only a few feet wide. Reliable estimates of settlement of sandy soils cannot be made from laboratory tests, because of difficulties in obtaining undisturbed samples, in maintaining a sample undisturbed while placing it in a consolidometer and in reproducing site conditions in which lateral flow of the particles can occur. Consequently, field tests are usually employed for this purpose. From theoretical, experimental and practical data Terzaghi and Peck[18] (1948) derived the equation

$$S_b = S_1 \left(\frac{2b}{b+1}\right)^2, \quad . \quad . \quad . \quad (10)$$

to represent the relationship between settlement and footing width on an unsaturated, homogeneous deep bed of sand, where S_b is the settlement of a square footing of width b under a given bearing pressure and S_1 is the settlement of a test plate one foot square under the same bearing pressure. When $b = 10$ ft., $S_b = 3{\cdot}3S_1$ and as $b \to \infty$, $S_b \to 4{\cdot}0\,S_1$. This equation is applicable also to continuous footings—in an empirical way—since the restraint afforded by a long footing to longitudinal movement of sand compensates for the compression of the sand at greater depths induced by the greater length of a continuous footing. Theory and experiment indicate that settlement on sand which is saturated to the underside of a footing located at or near the surface is approximately twice the settlement on unsaturated sand. Care is required in the interpretation of results given by equation (10), since the effect of variations in compressibility of deeper strata will not be apparent in the test observations owing to the small width of the loaded area. Because of the relatively high permeability of sands and gravels, water is readily expelled from the pores in these soils and the settlement is generally finished when the structure is completed and loaded.

ALLOWABLE PRESSURE ON COHESIVE SOILS

The allowable pressure on cohesive soils may be governed by either the shear failure or the settlement criterion, since even with a factor of safety of three for shear failure beneath a given foundation the settlement may be excessive. The settlement of structures founded on clays and plastic silts is generally a lengthy process because of the slow rates of extrusion of pore water. The magnitude and rate of settlement can be determined from laboratory tests with an oedometer or consolidometer.

When an excavation is made there is a tendency for the soil in the bottom to rise or heave an amount consistent with the relief in pressure equal to the weight of the excavated soil. However, the bottom becomes re-loaded during the process of placing the foundation and erecting the superstructure and generally the heave is reduced to zero shortly after the load equals or slightly exceeds the weight of the original overburden. When the structure is completed and loaded, the amount by which the bearing pressure exceeds the original overburden pressure is the net loading intensity.

Now the vertical pressure due to the net loading intensity on horizons beneath a foundation gradually decreases with increase in depth and for a single foundation becomes less than 10 per cent. of the average contact pressure when the depth is equal to about twice the width of the foundation. The vertical pressure p_1 at any point on any horizon due to a given net loading intensity distribution can be calculated from the appropriate Boussinesq equation; the calculations are facilitated by the application of charts devised by N. M. Newmark. The amount of consolidation developed at any point on a horizon depends on the calculated vertical pressure p_1 at that point. Undisturbed soil samples are taken at various horizons from boreholes and tested with drainage at top and bottom surfaces in a consolidometer over a range of pressures which includes the overburden pressure p_0 and also $(p_0 + p_1)$. The amount of consolidation of a specimen is usually determined by consideration of changes in void ratios but the following details illustrate the calculations which are made in a simple case.

CALCULATION OF ALLOWABLE PRESSURES

Assume that a bed of clay of thickness H, with beds of sand above and below, is sufficiently thin for the average of the net vertical pressures on the top and bottom of the bed to be taken as the consolidating pressure p_1 throughout the whole thickness. If a sample of the clay, of thickness h when under pressure p_0, decreases in thickness by an amount δh under the increment of pressure p_1 when tested in a consolidometer, then the settlement to be anticipated is

$$\delta H = \frac{\delta h}{h} H. \quad . \quad . \quad . \quad (11)$$

If the time taken for 90 per cent. of the settlement δh to occur is t_1, then the estimated time required for 90 per cent. of the settlement δH to occur is

$$t_2 = \frac{H^2}{h^2} t_1. \quad . \quad . \quad . \quad (12)$$

If the bed beneath the clay is impervious, then the time becomes four times t_2 because drainage from the clay bed can take place only at the top of the bed and the drainage path is longer than when drainage takes place at both the top and the bottom. These calculations are the simplest which can be made for estimating consolidation settlement and, although they are adequate for relatively unimportant structures where site conditions are as straightforward as those indicated above, estimates for other conditions are influenced by factors which are outlined below. The time taken for 100 per cent. consolidation to take place under a given pressure is theoretically infinite and it is usual to determine the time required for 50 per cent. or other convenient percentage of the settlement to occur.

The intensity of vertical pressure on different horizons in the soil decreases with increase in depth and the general pattern of distribution for a uniformly-loaded foundation area is shown in Fig. 2 (*a*). Since consolidation increases with increase in pressure, the settlement beneath the foundation will be a maximum at the centre and a minimum at the edges. This dish-shaped settlement is characteristic of most buildings when founded on a number of independent pad footings—the interior footings usually settling more than the exterior. In the case of a raft founded at a shallow depth in sand, the settlement may be dome-shaped; this is discussed later. The vertical distribution of pressure beneath the centre of the foundation is shown in Fig. 2 (*b*), together with the existing overburden pressure. Where a foundation is located at a depth below ground level the pressure inducing settlement is, of course, the net loading intensity.

CALCULATION OF RATE OF SETTLEMENT ON A THICK BED OF CLAY

Where a foundation rests directly or indirectly on a thick bed of clay the magnitude of the settlement at any point on the foundation can be determined by dividing the bed into a number of layers, say, 5 ft. thick, and calculating the settlement in each layer under the average pressure in the layer given by a net pressure distribution such as that shown in Fig. 2 (*b*). Calculations for the rate of settlement are complicated by the fact that the vertical distribution of pressure is not uniform, as it is in the thin layer tested in the consolidometer, and on which the calculations are based. Factors for the rate of settlement under standard geometrical types of pressure distribution have been determined from the mathematical theory of consolidation and are published in a number of texts. The distribution shown on the right of Fig. 2 (*b*) is approximately an inverted triangle and factors can be selected from the published data for such a geometrical distribution. The errors involved are not usually of great consequence since the bed of clay is thick, consolidation will continue for many decades and whether it takes 30 years or 40 years to reach 90 per cent. of the total settlement is not likely to concern the designer—it is generally sufficient to know the order of time involved.

Settlement on clay usually commences as soon as

construction of the foundation is started—even though initially it may involve reduction in heave—but it continues for a considerable period of time after construction is completed and the characteristics of a time/settlement curve for a structure founded on clay are shown in Fig. 2 (*c*). The loading employed in the analysis of bearing capacity or in the design of foundation or superstructure is generally the maximum dead and live loading, although under transient loads it is sometimes permissible to increase the working stresses slightly. However, consolidation of clay is lengthy, transient loads may have no effect on settlement and consequently the loading employed to estimate settlement may be less than the loading employed in stability calculations. Nevertheless, settlement on sand occurs more rapidly and it may be desirable to take full dead and live load into account. If the loading is in the nature of a high-frequency vibration then settlement on sand may be excessive.

The delay in consolidation of clay is due primarily to the expulsion of pore water but there is in addition a plastic lag known as secondary compression which is most marked when the amount or degree of consolidation exceeds about 80 per cent. and affects calculations for rate of settlement. It is not catered for in Terzaghi's mathematical theory of consolidation but methods have been devised for making corrections for this effect. Terzaghi and Peck[18] (1948) state that the rate of secondary settlement of buildings founded on normally loaded clay during the first decades following construction ranges between $\frac{1}{8}$ in. and $\frac{1}{4}$ in. per annum and exceptionally as much as 1 in.

Skempton[13] (1951) has examined immediate and consolidation settlement data derived from laboratory and field observations and has developed equations from the theory of elasticity whereby the immediate settlement ρ_i for a particular foundation resting on a homogeneous mass of clay can be calculated. The equations are of the form

$$\rho_i = \frac{K_1 p b}{E} \quad . \quad . \quad . \quad (13)$$

where K_1 is a factor depending on the shape and rigidity of the footing and Poisson's ratio for saturated soils with no water-content change (taken as 0·5), p is the bearing pressure, b is the breadth of the footing and E is the secant modulus of elasticity obtained from an unconfined or triaxial compression test over a range of stress from zero to p. The considerations from which this type equation has been derived are based on the similarity between load/settlement curves obtained from site loading tests and stress/strain curves obtained from unconfined and triaxial compression tests over ranges of stress up to well over half the ultimate values.

Where clay exists as a relatively thin layer beneath a foundation or where a foundation rests on sand or gravel overlying clay, the immediate settlement is small owing to the lateral restraint imposed on the clay by the adjacent comparatively rigid layers and total settlement can be calculated by the consolidation theory outlined earlier in this paper. Where the foundation rests on a thick bed of clay the problem is more complicated and Skempton (1951) has derived equations whereby the total final settlement ρ_n, including immediate and consolidation components, can be calculated approximately for this case. The equations are of the form

$$\rho_n = K_2 m_v p b \quad . \quad . \quad (14)$$

where K_2 is a factor depending on the shape and rigidity of the footing, m_v is the compressibility of the clay derived from consolidation tests and is dimensionally the inverse of a pressure, p is the bearing pressure and b is the breadth of the footing. Equation (14) is similar in form to equation (13), since m_v and $\frac{1}{E}$ are dimensionally equivalent. The error in settlement calculated from equation (14) is not likely to exceed $\pm$ 40 per cent. of the settlement calculated by the more comprehensive theory but estimates within these limits of accuracy are often sufficient for practical purposes. An important conclusion to be drawn from equation (14) is that settlement of geometrically-similar foundations on a given cohesive soil under a specified pressure is proportional to the breadth of the foundation or, alternatively, that the bearing pressure leading to a given amount of settlement is inversely proportional to the breadth.

DIFFERENTIAL SETTLEMENTS

To conclude this paper it is desirable to discuss briefly the effect of differential settlement on structures. Terzaghi and Peck[18] (1948) state that most ordinary structures, such as office buildings, flats and factories, can stand a differential settlement between adjacent columns of $\frac{3}{4}$ in. The effect of cladding on settlement can be examined in the light of experimental work reported by Thomas[19] (1953) who discusses the results of tests on a frame of internal dimensions 11 ft. × 9 ft., constructed of steel and encased in concrete, to which a racking load was applied by two point loads at diagonally opposite corners (Fig. 2 (*d*)). To summarise the results in a general form, the approximate loads required to cause a displacement of 1 in. at, and in the direction of, the load are as follows for the panel filling specified:

No panel filling	13 tons
Panel filling of 3 in. hollow clay blocks	28 tons
Panel filling of 4½ in. brickwork with central door opening	33 tons
Panel filling of 3 in. clinker blocks ..	35 tons
Panel filling of 4½ in. brickwork ..	47 tons

In the experiments, yield of the frame with the clinker panel commenced just before the 1-in. deflection occurred. It should be observed that deflections increased after yield had occurred as the load was gradually reduced and when the load reached zero the deflection was 14 to 15 in. for all the combinations mentioned above. The ultimate load with the open frame was 20 tons and occurred at a defflection of about 2 in., and the greatest ultimate load, achieved with the 4½-in. brick panel, was about 52 tons and occurred at a deflection of about 1½ in.

Now consider the effect of a vertical settlement of 1 in. at the foot of one column in a building frame; assuming that 11 ft. × 9 ft. is an average size for the panels. The magnitude of the bending moments induced in the frame would be the same irrespective of whether the panels are, or are not, filled, if it were not for the fact that the distribution of moments will be modified by local restraint at various points on individual members due to the panel filling. However, according to these tests, the load required to produce 1 in. deflection when the panel is filled with 4½-in. brickwork and including a door opening—a condition obtaining frequently in practice—is two and a half times that required to produce 1-in. deflection when the panel is open. It is obvious therefore that a building frame consisting of a number of columns and beams is considerably stiffened as a whole by filling in the panels and that, as a result, even slight settlement under one column will readily lead to a transfer of load to adjacent columns at which slight increases in settlement will occur. This work confirms the observation that most buildings will withstand a differential settlement between columns of $\frac{3}{4}$ in. without structural distress; in the experiments the ultimate load was reached with deflections of $\frac{3}{4}$ to 1½ in., except for the open frame where ultimate load was reached at 2 in. deflection. In practice, the dimensions of panels are somewhat larger than those of the test panels and consequently the effect of $\frac{3}{4}$ in. of differential settlement would be less, although cracking of plaster and similar effects would undoubtedly be experienced.

The tests described above are only a few of many being carried out with a view to evolving methods of analysis for clad framed buildings based on the concept of composite construction. It is interesting to reflect on the possible consequences of adopting these new methods of design. If a clad framed building is designed by the elastic analysis as an unclad frame—as it normally is—with a factor of safety of three, then the real factor of safety, or more correctly, the load factor, is much greater than three owing to the self-supporting and stiffening effect of the cladding and the ameliorating effects of plastic yield. Consequently, such a structure is unlikely to show distress if it is inadvertently overloaded by, for example, deficiency of support beneath the foundation of one of the stanchions. If now design is based on composite construction then the load factor will be no greater than the design value of, say, three and overloading may conceivably cause some distress in the building. Obviously when composite construction design methods become current—as they certainly will—greater attention must be paid to dead and live loads and to stability of foundations.

The significance of settlement as a factor which is as important as bearing capacity—if not more so—was discussed at length by Terzaghi[16] in 1935. Although much of the contents of this paper has been synthesised in more recent texts, the original can be commended to interested engineers because of the wealth of observation and analysis which it contains.

The second part of this article, including a complete list of references, will be published in a subsequent issue.

SHIPS' HULLS PROTECTED

ULTRASONIC VIBRATIONS MAKE BARNACLES UNCOMFORTABLE

Ultrasonic vibrations have been successfully used to discourage barnacles from settling on the hulls of ships, and to inhibit the growth of barnacles already there. Tests are continuing but already it seems that the method is effective without harmful results to any apparatus or structure of the ship. The method of producing the vibrations is to solder a transducer on to a plate, weld the plate to the inside of the ship's hull, and induce vibrations at a frequency of between 23 and 27 kc/s into the hull plates through the transducer. The vibrations, which are sonic rather than mechanical, make the hull an unsatisfactory resting place for barnacles.

In the development of barnacles there is a larval stage in which the barnacle is mobile, and during this stage it must settle within a few hours or die. It appears that the barnacle has a measure of choice when it comes to settle, and that settlement is not an instantaneous and automatic response to contact with a surface. Most fouling through barnacles takes place in harbour, and in harbour the barnacle larva probably has the choice of settlement on the hulls of several ships or on the harbour installations. If a particular hull vibrates continuously in a way that can be sensed by the barnacle, the barnacle will almost certainly decide to find a more congenial and suitable resting place. The effect on the barnacle is only psychological, for with the powers used no physical injury can be caused.

Ultrasonic anti-fouling has been developed and tested by Postans, Limited, Trevor-street Works, Birmingham, 7. In the latest tests, those on the P. and O. twin-screw Diesel ship Soudan, 9,080 tons, one transducer was used, the power for which was supplied by a 1 kW ultrasonic generator. The Soudan sailed to the Far East in October, 1954, and returned after five months. She was examined in dry dock at Rotterdam, and her hull appeared to be clear. In April this year she sailed again and returned after four months; once again the hull appeared to be clear when examined in dry dock.

A number of other tests have been made, one of the most striking being the first one. Two painted steel plates were used, each 6 ft. by 1 ft. 6 in. Both plates were immersed in sea water, one as a reference plate, and the other equipped with a transducer powered by a 250 watt 23 kc generator. The test began in the summer, and by the autumn the reference plate was covered with a variety of plants and animals, whereas the vibrated plate only supported a sparse and stunted growth of a single species of alga. As a result of this initial test other tests were planned for sea-going craft, the latest of which were those carried out on the Soudan.

Possible ill effects of the ultrasonic vibrations concern the compasses, radio, radar, asdic, metal fatigue, painting, corrosion, fire, passengers and crew. No detrimental effect has been reported on compasses, radio or radar, paint, or crew during the experiments. Fire risks should be no greater than with any other electrical equipment. Interference with asdic is a possibility; an obvious cure is the selection of frequency. Asdic experience shows that no metal fatigue or enhanced corrosion occurs.

The advantages of using this method of anti-fouling are partly in time and partly in money. There would be a saving in paint, time spent in painting, and time spent dry-docking; fuel consumption would be reduced because of the reduced drag on the ship's hull. Against these savings there is the cost of the equipment, the power to run it—which would in general be small, because the average size would only be 3 kW—and the cost of maintenance. The scheme must still be completely proved, but it seems to offer considerable savings.

BRITISH ASSOCIATION MEETING AT BRISTOL

NUCLEAR REACTORS: MOTOR TRANSPORT

Continued from page 369

Session B of the meeting on Friday morning, September 2, was devoted to the subject of nuclear reactors for power production. Dr. Willis Jackson took the chair for the first paper, which was by Dr. J. V. Dunworth, head of the Nuclear Physics Division at Harwell, and was entitled "The Methods of Using Fuel in a Nuclear Power Programme." In it the various types of reactor which might be built and the different ways of using nuclear fuels in a nuclear power programme were considered. We hope to reprint the paper in an early issue of ENGINEERING. After it had been presented by the author the chairman invited discussion and several members asked questions to which the author replied.

USING NUCLEAR FUEL

In reply to a question, Dr. Dunworth said that in the unlikely event of a reactor becoming completely out of control nothing very much would happen beyond the melting of some of the interior. This had been tried both intentionally and unintentionally. It was not a serious problem, but if anxiety were felt it was possible to put a large container round the reactor. At Harwell, for instance, a building had been put round one of the experimental reactors; but it was very unlikely that a reactor would become out of control, because it would not be built if there were much danger of that happening. With regard to the risk to public health from waste products, Dr. Dunworth said that with a well-managed project there was no reason why anything at all should leave the factory, so that there would be no danger. In no design which was ever likely to be used in the future would water be passed through the pile and when it was used as steam in the turbo-generator it would never be blown off. A closed-cycle system would always be used and any radio-activity would be removed before the water was discharged to waste.

Dr. G. H. Rawcliffe, Professor of Electrical Engineering in the University of Bristol, said he was a little concerned regarding the effect which the large-scale Press publicity on atomic energy would have on the distribution of scientific talent in the rising generation. A situation might arise in which all the young men studied atomic energy and the production of heat from it and none were concerned with the production of electrical energy from the heat. In reply, Dr. Dunworth said he thought the situation would even out; in fact, at the moment atomic energy was having to take second place to space travel in the minds of the young.

Dealing with a question which had been raised regarding the quantity of uranium ore which had to be brought into the country, Dr. Dunworth said the actual consumption of the whole country for electricity production would be about 15 tons per annum, which could be brought in by aircraft. As time went on the stage would be reached when the whole fuel supply for a reactor would be purchased at the time it was built. It would continue to use the same fuel throughout its life and the fuel would be sold when the reactor was finished with and dismantled. Admittedly, there was only about 3 per cent. of uranium in the ore, but obviously any primary producer would be interested in refining it and the refined product would then be imported. There was, in fact, some uranium in this country, but at the moment it was not economic to extract it.

With regard to the reactor equipment, as distinct from the fuel, there was no doubt that reactors could have a very long life. The old idea that reactors could not be maintained had been disproved; one pile had, in fact, been rebuilt after an accident for about 10 per cent. of the original cost. The technique of maintenance was being rapidly learnt and obsolescence would be the limiting factor.

To a member who asked whether it were necessary to be a brilliant first-class honours man to work on atomic projects, Dr. Dunworthy replied that there was really nothing special about the work; it had been surrounded by an aura of secrecy and mystery, but it was a perfectly ordinary subject. He did not believe, however, that it would become what might be called purely conventional engineering but would always have a strongly scientific flavour and much of it would be in the tradition of chemical and aeronautical engineering. The most successful people were those who had an adequate knowledge of both and then forgot that they belonged to either.

On the motion of the chairman a vote of thanks to the author for his paper was accorded and a film produced by the Iron and Steel Federation entitled "Steel in Atomic Energy" was then shown.

DESIGN AND OPERATION OF NUCLEAR REACTORS

After a brief interval, the second paper, by Mr. H. H. Gott, also of Harwell, was taken, Dr. Dorey, President of the Section, acting as chairman for the remainder of the session. Mr. Gott's paper was entitled "The Design and Operation of Power Producing Reactors," and this paper will also be reprinted in a forthcoming issue of ENGINEERING.

In reply to points raised in the discussion which followed the presentation of the paper, Mr. Gott said the efficiency of 20 per cent. mentioned was the overall efficiency, including the steam-generating plant. With regard to the steel liner, sufficient experience had been gained to enable him to state that it was unlikely that its structure would be affected to an extent that would necessitate its replacement. It was purely a type of insulating material, except that within the liner there was a thickness of 2 or 3 in. of steel which had a stress function and because of its position it would be subjected to a higher level of radiation than the other parts, so that the question as to whether the mechanical strength was affected by radiation was much more important in this case.

With regard to the absorption of the energy of the gamma rays, this energy was taken up by various transformations in the nuclei of the shielding material, although ultimately it would reappear as heat in the concrete shield, but the relation between gamma-ray energy and heat was such that a comparatively small amount of heat energy corresponded to a very dangerous amount of gamma energy.

Mr. B. R. Campbell-Kelly asked whether the distance between the uranium rods in the moderator was determined from the mean free path of the neutrons at the working temperature and also whether there was any self-generation within the rod of uranium itself due to the fast-moving neutrons. In reply, Mr. Gott said the distance was determined by a consideration of the mean free path and diffusion lengths and the absorption by impurities in the graphite. There was a certain amount of self-generation of the type suggested, but it was fair to say that sufficient data were available from experiments to enable the necessary calculations to be made. With cadmium control rods all that was necessary was that there should be a sufficient distribution of cadmium—or boron, as was more usual—control rods to absorb the necessary amount of neutrons. It was comparatively easy to design an arrangement which would give adequate control. In general terms it was essential that they should be in the centre of the reactor and that they should move quite slowly. Whether they were placed parallel with the uranium rods or transversely did not seem to matter, but the arrangement of the graphite structure and the general arrangement of the pile structure, the sheathing and the control system as a whole might be greatly influenced by the way it was done. It was best to prepare alternative schemes before deciding which to adopt.

To a question as to the temperature reached in the reactor, Mr. Gott replied that aluminium, magnesium, or some material which had a relatively low melting point was used, so that temperatures could not exceed about 450 deg. C. It was possible to get cooling-down temperatures of about 300 deg. C., so that as far as steam generation was concerned, they were back to the early 1930's.

Another speaker said that a statement in the paper to the effect that the neutron absorption capacity of the concrete shield was a function of the amount of water in the concrete, seemed to contradict another statement that high-density concrete had the maximum absorption which would be obtainable theoretically with no water but with solid granite aggregate. In reply, Mr. Gott remarked that if the speaker looked into everything that had been said he would find some apparent contradictions. In the paper he had said that for heat transfer purposes it was necessary to use a lot of shielding material on the uranium. This, however, was very bad for neutron absorption, and the decision just where to strike the balance was the whole art of the design. High-density concrete was rather for the absorption of gamma radiation than for neutron absorption and if a shield were designed to absorb the neutrons only it would be made rather thinner than one which would absorb all the gamma radiation.

To a speaker who asked if the uranium rods could be made in the form of tubes, Mr. Gott replied that there were other types of reactors in which tubes were used but tubes presented a problem because with a rod it was comparatively easy to put a sheath on the outside of it and make welded joints at the ends which gave a good sound job. A tube, on the other hand, would need to have a large bore in order to get the coolant through and the sheath would have to be placed internally; the thermal expansions would then be in the wrong direction. There were, however, advantages and disadvantages in either case.

Referring to the film shown in the meeting, a speaker said it appeared that a good deal of electrical energy was used for making the actual fuel. Taking Calder Hall as an example it would be interesting to know how much of the power produced would be required to make its own fuel; in other words, to extract the fuel from the ore imported. Mr. Gott, in reply, said he thought there might be some misunderstanding. A lot of power was used to separate the 235 isotope from natural uranium, but the amount of power that went into the reactor was not very large considering the output. It was preferable to use natural uranium for reactor construction because this involved only ordinary chemical processes; the only electrical power used was that required for melting furnaces, pumps, etc., in the chemical plant.

Finally, a member, referring to the vertical insertion of the uranium rods, asked if there were not a maintenance problem if the container of an individual rod disintegrated. He thought it would be extremely difficult to extract the fragments and might put the whole reactor out of action unless arrangements were made for the removal of the fragments from the bottom. In reply, Mr. Gott said that such arrangements could be made but he did not think the trouble was likely to occur; if it did it would be possible to get the pieces out at the top.

This concluded the discussion and in proposing

a vote of thanks to the author the chairman said that in order to progress on sound lines it was necessary to have what might be called full-scale experiments and indeed as engineering structures became more complicated that was the only way of proving them satisfactory.

The vote of thanks to the author, and to the United Kingdom Atomic Energy Authority for releasing the information, was accorded with acclamation and the members then adjourned to a nearby cinema for the first public showing in this country of a colour film entitled "Calder Hall," Britain's first atomic power station, which will be completed next year.

"CALDER HALL" FILM

Introducing the film, Sir John Cockcroft said it was the first visual report on the atomic power station now being built in Cumberland, which was being designed and constructed by the Industrial Group of the Atomic Energy Authority under the leadership of Sir Christopher Hinton. The power station, he said, consisted of normal steam turbo-generator sets, the heat required being provided by two nuclear reactors consisting essentially of large pressure drums about 40 ft. in diameter filled with graphite blocks having a number of channels running through them in which cartridges of uranium were located. The graphite-uranium matrix was cooled by a gas which entered the pressure vessel at the bottom, passed up through the matrix, being heated in its passage, and leaving the vessel from the top. The hot gases then passed through a heat exchanger, which was a vessel about 80 ft. in height by about 18 ft. in diameter, the heat being imparted in this to a water circuit forming the steam which supplied the turbo-generators. The cooled gases, after passing through the heat exchanger, were returned by a fan to the pressure vessel and passed again through the graphite-uranium matrix, being continuously circulated in this way. It was anticipated that the Calder Hall power station would produce more than 50 megawatts of electrical energy which would be fed into the National Grid. It was the first of 16 power stations in the planned programme.

MOTORWAYS

The first paper taken when the meeting was resumed on Monday, September 5, was one by Mr. J. A. Proudlove on "Motorways," which was presented by the author in Session A. This paper is reprinted elsewhere in this issue and is the subject of comment in Weekly Survey. The chair was taken by Mr. G. O. McLean, a vice-President of Section G.

The discussion was opened by Mr. J. Rosen, who remarked that the paper was based mainly on what had happened abroad, the author being apparently unable to quote experience from this country. Mr. Rosen asked why we were so far behind other countries in respect of motorways and, having fallen behind, if we were still to be handicapped by the exigencies of the present economic situation. He also asked if the author considered that we could get ahead with motorways in the near future.

In his reply Mr. Proudlove said that this country probably had the best minor road system in the world and that might be the reason why the through routes had suffered. Whether we could afford the necessary finance for motorways was a matter for the economists but they appeared to agree that it was a capital investment that ought to be made. He did not know whether we could catch up with other countries but we would do so if we were wise, in which case we might eventually have the best system of all as we could benefit from the experience and the mistakes of other countries. We were fortunate in that the distances involved in this country were rather less than in some others. The most urgent problem, he considered, was to tackle the approaches into urban areas and then construct the motorways.

Mr. J. D. Desmond said the author's illustrations of motorways in Germany and Holland appeared to indicate a very low traffic density compared with that in this country. He wondered whether that was the result of the higher average speed or whether the traffic density was actually much lower than it was here. Regarding accidents he pointed out that if the number of vehicles were doubled in the next ten years the chance of collisions would also be doubled and with twice as many vehicles the total number of accidents would possibly be quadrupled. That underlined the urgency of the whole road situation.

On this point the author said that if we had in this country roads of the standard of the Continental countries the apparent density of the traffic here would not be very different except at the week-ends and during holidays. Highway engineers accepted the fact that, even with motorways, there would be some congestion at holiday periods, but it was not economic to build routes based on the traffic needs on a few occasions during the year, particularly as the peaks might only last for an hour or two in the morning and evening. It was at the entries to the urban areas that the main congestion occurred and he repeated that these should be dealt with first.

Dr. A. E. Russell, recalling the estimate that the present cost of building roadways was £200,000 to £300,000 per mile, asked whether the British method of using picks and shovels was to be continued or whether a start had been made to construct machinery for the work. He called attention to the opportunity afforded engineers to develop equipment which would do the work on a production line basis.

Mr. Proudlove replied that undoubtedly there would be a great change in construction techniques. Several firms in this country were interested in the provision of machinery for stabilising construction. He thought it probable that British design was hampered by lack of experience as the matter had not been gone into here on the same scale as it had been in Germany and America.

On this point Professor W. Fisher Cassie said he felt it would be wrong to give the impression that Britain was lagging behind in respect of equipment; we had equipment equal to any in Germany. It was an economic and political problem rather than a technical one. He emphasised the importance of regarding motorways not simply as roads and urged that they were almost systems of life; they raised social problems. In Germany, there was a body which controlled the roads, restaurants, filling stations, etc., and great attention was given to amenities. If a car broke down the driver would go to the nearest telephone on the side of the route and on picking up the instrument was automatically connected to the nearest repair depot of the *Autobahnen* control.

Another speaker referred to cracking on concrete roads and in reply Mr. Proudlove said there was no excuse for building a bad concrete road. Dealing with a question regarding the capital cost contribution to the total mileage cost or the ton-mileage cost he said it was not possible to make complete calculations until long lengths of motorways had been built. By that time he hoped that new legislation would have been passed permitting commercial vehicles to travel at speeds up to 50 m.p.h. in safety and more economically than they could be operated at present. It would then be possible to appreciate the real economic results.

Finally, a speaker referred to the difficulty due to the effect on concrete roads of severe and prolonged frost. The effects could be disguised to a considerable extent by a bituminous carpet, but he was anxious to avoid the impression that it was necessary to make a concrete road first and then put bitumen on top of it. In the United States there were hundreds of miles of motorways in which concrete was not used at all; the system was to provide a hard core stabilised foundation and work up from that to a bituminous surface. Such roads were flexible and did not break up in cold weather or develop cracks and bumps. The worst that could happen was that the roads might become slightly wavy if the foundations were not completely stabilised before the top surface was laid.

MOTOR VEHICLES AND THEIR DESIGN

After a brief interval the next paper by Mr. J. N. McHattie, on "Motor Vehicles and Design" was taken, the President of the Section, Dr. S. F. Dorey, occupying the chair. The paper was published in our issue of September 9, on page 344. The first speaker in the discussion which followed the presentation of the paper was Wing-Commander T. R. Cave-Browne-Cave, who, referring to the way in which suggestions for improvements could be injected into the complex organisations described by the author, mentioned as an example that some time ago the Motor Industry Research Association had put to him a problem concerning the heating and ventilation of passenger-service vehicles. He had found that the improvement desired was to increase the amount of ventilation, and as that was done the heating had also to be increased. A solution which had proved fairly satisfactory was to remove the radiator from its conventional position in front of the engine and replace it by two carefully designed radiators located in the space on each side of the destination box. Air passed through them due to the forward motion of the vehicle and gave good ventilation without any fan. During summer the outlets were opened at the side and the air entered at the point of maximum pressure leaving at the point of lowest pressure. In cold weather a temperature some 15 deg. above the ambient temperature could be maintained in the vehicle and it was possible to effect 20 changes per hour. The system had proved very satisfactory in service. He asked the author from what source improvements originated, whether primarily from the sales departments or elsewhere. He mentioned also that many cars appeared to get into serious trouble when moving slowly in a long queue up a gradient. It seemed that considerable improvement could be effected in that respect.

Mr. McHattie, referring to the sources from which suggestions for improvements originated, said the main difficulty was to separate the wheat from the chaff. Most manufacturers were inundated with ideas for improvements most of which were completely useless; but they all had to be investigated and the difficulty was to determine which were worthy of development and which were not. For his system of heating and ventilation Wing-Commander Cave-Browne-Cave had chosen a much more receptive field than motor-car manufacture, for public-service vehicle production was much more flexible and the manufacturers, in general, were more receptive of ideas provided they were not too costly to develop. The Motor Industry Research Association undertook most of the research into general problems and consulted specialists in particular fields from time to time, but could not investigate the problems of individual manufacturers.

To a comment on the "dragon's teeth" design at the front of cars, he said that in the early days the obvious thing was to put the radiator right in front where it was exposed to dirt and damage; but it was soon realised that the proper thing to do was to put it farther back and guard it with some sort of cowling. An opening of some kind had to be made and to prevent the ingress of birds and foreign bodies some bars had to be provided, but if all manufacturers just put in bars all cars would look alike. The Americans, however, had led the way in early styling, setting fashions to obtain new sales, and the frontal aspect obviously lent itself to alterations. The Americans had a rather more flamboyant taste than ours in the matter of decoration and the dragon's teeth were the regrettable outcome.

A speaker asked if the problem of condensation inside vehicles was receiving attention by the research departments, remarking that there were devices to prevent condensation on windscreens but nothing appeared to be done to

prevent it on side and rear windows. In reply, the author said the matter was under investigation but he could not claim that any great progress had been made towards a remedy. To avoid condensation it was necessary to make the temperature inside the glass as nearly as possible equal to that outside. It was comparatively easy in the case of the windscreen which was 18 in. or so from the driver and the air passed up the screen and over his head. It was a much greater problem to introduce a stream of cold air for de-misting the side and rear windows in such a manner that it would not cause discomfort to the passengers. The alternative was to heat the windows either electrically or with hot air. Electrically-heated glass was available with the heating elements inside the glass and practically invisible, but it was very expensive and not a proposition for the ordinary quantity-produced car. In addition, the problem of conducting warm air to the windows, particularly the rear window, was being investigated; the side windows could be dealt with more easily as they were easy to reach.

Wing-Commander Cave-Browne-Cave finally commented that the problem was the same as in the case of the 'bus he had mentioned and the cure was to pass sufficient air through the saloon to get rid of the moisture.

The discussion having been completed, the session was adjourned.

To be continued

DIRECT CONVERSION OF RADIATION INTO ELECTRICAL ENERGY

RADIOISOTOPES AS AN AUXILIARY POWER SOURCE

If the energy of a disintegrating atomic nucleus could be converted directly and efficiently into electrical power, most of the technological problems now associated with the use of nuclear reactors would not arise. There seems, unfortunately, no immediate or certain prospect of achieving this result on any great scale. Methods of transforming radiation into electrical energy in small quantities have been devised, however, and about a dozen research organisations in the United States are engaged on studies in this field; no doubt similar work is being carried out elsewhere. It appears that the main object of this research is to produce simple, compact and long-life power sources. In this case direct conversion means a process in which there are no intermediate steps such as the evolution of heat or the driving of a turbo-generator, and refers specifically to the transformation of radiation from radioactive isotopes. During the International Conference on the Peaceful Uses of Atomic Energy at Geneva a paper on this subject entitled "The Direct Conversion of Radiation into Electrical Energy," was presented by E. G. Linder, P. Rappaport, and J. J. Loferski, of the Radio Corporation of America. The paper, which is published here in shortened form, was delivered on Saturday, August 20, and dealt in particular with researches carried out at the R.C.A. Laboratories at Princeton, New Jersey.

The total power available from radioisotopes is limited by the supply of fission products, which is itself contingent on the use of nuclear reactors as the main source of electrical power. It has been estimated that if all the electricity now consumed in the United States were obtained from nuclear reactors then the annual output of radioactive wastes would be only sufficient to produce electrical power at the rate of 400 MW; this represents a few hundredths of one per cent. of the energy consumed in the country, a figure which is further reduced by the low efficiency of conversion (a few per cent.).

Compared with the annual supply from batteries in the U.S., which is approximately 2 MW, this nevertheless represents a considerable quantity, and, although fission products cannot be regarded as a principal source of power they may be considered as a possible auxiliary source of some magnitude. The maximum output might be roughly equivalent to that produced by batteries at the present time.

CHARGED AND UNCHARGED RADIATION

The types of radiation under investigation may be grouped into two categories: charged radiation including electrons or beta rays, alpha particles, ions and fission particles; and uncharged radiation such as X-rays, gamma rays, neutrons and light if produced by some nuclear process. The most important sources of charged radiation at present are radioactive materials in the form of fission products and the most suitable are beta-emitters such as strontium 90-yttrium 90 and tritium or hydrogen 3. The electrical properties of one curie of each are given in the accompanying table.

TABLE.—*Electrical Properties of One Curie of Beta Emitter*

Property.		Sr90-Y90	H3
Disintegration rate	(per sec.)	$3{\cdot}7 \times 10^{10}$	$3{\cdot}7 \times 10^{10}$
Current	(amps.)	6×10^{-9}	6×10^{-9}
Average voltage	(volts)	5×10^{5}	6×10^{3}
Power	(watts)	3×10^{-3}	$3{\cdot}6 \times 10^{-5}$
Half-life	(years)	20	12·4
Weight	(gms.)	5×10^{-3} (100 per cent. pure)	—

The most plentiful radioactive source of uncharged radiation, the chief source of which is the sun, is the gamma emitter, cobalt 60, which has a quantum energy of 1·33 MeV and a half-life of 5·3 years. The radiation, like alpha particles, is too penetrating, however, to be suitable for power applications. A softer radiation and a longer life is desirable and Americium 241, which satisfies these conditions, may eventually be available in sufficient quantities to serve this purpose. It is of interest that by use of indirect processes or auxiliary materials such as phosphors, light may be obtained from emitters in this category.

Uncharged nuclear radiation has not been investigated as extensively as the charged kind with regard to direct conversion, and this may be so because the latter, by virtue of its charge, is less far removed from energy in electrical form, and is compatible with a larger variety of conversion processes. Another influential factor is probably the lower specific ionisation of the uncharged type. However, the conversion of uncharged radiation, in particular soft gamma rays, is worth further study. This view is supported by the promising results obtained in the conversion of solar light by semiconductor junction devices.

A further important consideration is the power available from a radiation source, and an electrode coated with a layer of radioisotope provides a suitable surface for this calculation. The emitted radiation is limited by the self-absorption of the isotope layer and increasing its thickness does not increase the radiation output indefinitely. For the strontium 90-yttrium 90 mixture it has been computed that the maximum power available is approximately 0·4 watt per sq. cm., corresponding to a layer about 2·5 mm. thick. Cobalt 60, in a 12-cm. layer, would have a power rating some 1,000 times greater. The cost of a limiting layer of either material would be prohibitive at the present time.

FOUR METHODS OF CONVERSION

The processes of direct conversion may be classified as follows: (1) direct charging methods —these may only be used with charged radiation and involve the simple collection of charged carriers by an electrode to create a voltage; (2) contact potential methods—both forms of radiation may be employed with contact potential fields serving to separate charges and produce currents; (3) thermocouple methods—either type of radiation is used to generate heat by simple absorption and the heat activates a thermo-

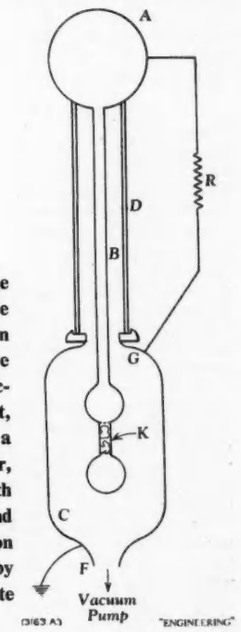


Fig. 1 High-voltage direct-charging device for converting radiation from a radioactive material (K) into electrical energy. This unit, which is in effect a self-charging condenser, may only be used with charged radiation and involves the collection of charged carriers by an electrode to create a voltage.

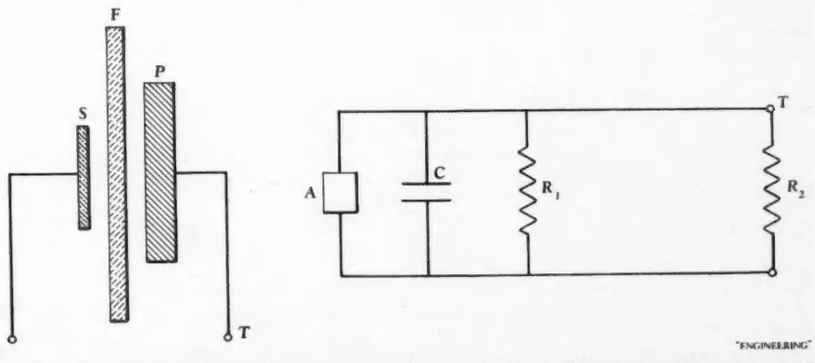


Fig. 2 Another direct-charging device has a radioactive source (S), a dielectric film (F) and a metal collector (P). A unidirectional flow of current occurs through (F) which is thin enough to pass beta particles but acts as an insulator to other forms of current. Right: equivalent circuit.

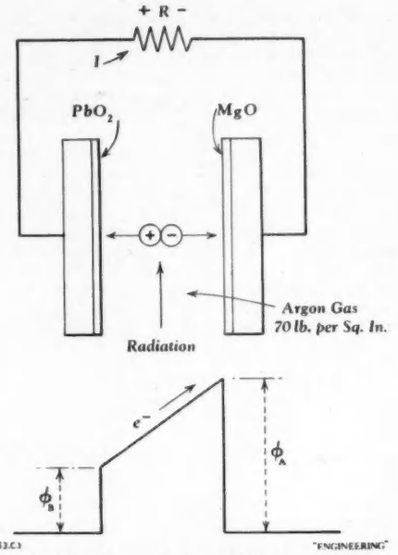


Fig. 3 In the contact potential system two electrodes of dissimilar metals are enclosed in an atmosphere of, say, argon gas. Radiation ionises the gas so producing carrier pairs which move to either electrode.

junction; (4) semiconductor junction methods—carriers are formed within the semiconductor by either kind of radiation and separated by the internal junction field. Other methods are possible but these categories cover most of the methods explored up to the present time.

DIRECT CHARGING

The first R.C.A. work on direct charging methods with which the authors were associated was started immediately after World War II, and was aimed specifically at power generation. A sketch of the apparatus is shown in Fig. 1. The radioactive material, which was strontium 90-yttrium 90, was contained in electrode K. This was connected by a supporting shaft B to the high-voltage terminal A. K was surrounded by a collector C. The high-voltage insulator D, separated and insulated the two terminals A and C. The collector C was evacuated so that negatively charged beta rays or electrons passed from K to C leaving a positive charge on K, and charging C negatively. This type of device is essentially a self-charging condenser. With a quarter of a curie of radioactive material, a voltage of about 365,000 volts was generated. The power produced was 0·2 milliwatt at an efficiency of 20 per cent.

This is a comparatively high efficiency, but unfortunately the characteristics of this particular device did not lie in a range practical for wide application. The available current was only about 10^{-9} amp., and the impedance was about 10^{14} ohm. However, it is possible for the current to be increased and the impedance decreased by using larger quantities of radio-active material. The limitations on this are largely economic at the present time.

Fig. 2 shows a second type of direct charging device. R.C.A. work on this began in 1950 and was first published in 1953. The unit has three main parts: a radioactive source S, a dielectric film F and a metal collector P. A unidirectional flow of current occurs through F, which is thin enough to pass beta particles but acts as an insulator for other forms of current. This system can produce several thousand volts, but, as in the first type, current and impedance depend on the amount of radio-active material used. Direct charging methods will thus become more feasible commercially as fission products become cheaper and more plentiful.

CONTACT POTENTIAL

The basic principle of the contact potential method is illustrated in Fig. 3. Between two electrodes of dissimilar metals is enclosed an atmosphere of gas such as argon. Radiation of any kind having sufficient energy to ionise the gas will produce carrier pairs. These will be affected by the field, owing to the contact potential difference of the metal surfaces, so that the positive ions will flow in one direction and the negative electrons in the other. This produces an electric current which may pass through an external load R and thereby do useful work. The device has a particularly low efficiency due mainly to the low absorption coefficient of gases for radioactive radiation, and their high ionisation energy (about 30eV) as compared to semiconductors (about 1eV). However, the efficiency may be somewhat improved by using low-energy radiation or gas under pressure.

THERMOCOUPLE CONVERSION

The third or thermocouple method converts radiant energy directly into heat and this in turn to electricity by means of the thermoelectric effect. If the absorption of the radiation is complete, and in practice it could be made nearly so, the efficiency of the method would be that of the thermojunction. Since the efficiency increases with junction temperature difference, it will in general be low for low power inputs. A thermocouple device of this type using polonium 210 has been investigated, and with 57 and 146 curies the electrical power delivered to a load was respectively 0·1 and 0·2 per cent. of the power developed as heat. The maximum output was 1·8 and 9·4 milliwatts respectively. Using solar radiation, efficiencies of about 1·0 per cent. have been attained, and by using concentrating reflectors or lenses it is estimated that an efficiency of about 5 per cent. would be possible.

SEMICONDUCTOR METHOD

The fourth or semiconductor method is one in which there has been much recent interest, and the first work in this field was reported by P. Rappaport in 1954. This method employs a *p-n* junction of materials such as silicon, or germanium. By a simple process utilising the internal electric field of the junction the radiation energy is converted directly into electrical energy. When electromagnetic radiation is used the process is called the photovoltaic effect, and when electrons are used it is termed the electron-voltaic effect.

The details of a typical device are shown schematically in Fig. 4. The junction itself may consist of silicon, for example, with *p*-type on the left and *n*-type on the right. A lead is connected to each of these regions by means of an ohmic contact. These leads in turn are connected to a load resistance R_L. To the left of the junction in the diagram is shown a source of any type of ionising radiation.

On the left of the figure the internal conversion process is shown, indicating the energy levels in the *p*-region, and *n*-region, and in the intermediate region where the junction occurs. Each of these regions contains a filled band, a forbidden band or empty gap and a conduction band. As indicated, there is an internal electric field in the region of the junction. Incident ionising radiation creates free carrier pairs, while the electrons are raised into the conduction band, and the holes remain in the filled band. These carrier pairs diffuse to the junction region where they are acted upon by the electric field in the junction, so that the electrons move to the right and the positively charged holes to the left. Thus an electric current is created due to the motion of these charged particles. This current may then flow into an external circuit and do useful work.

Fig. 5 illustrates an equivalent circuit for this type of unit. The short-circuit current I_s produced by the bombarding radiation is shown as generated by the current generator on the left. This current divides into two parts, the first of which, I_j, flows back through the junction, and the second, I, flows through the load R_L.

The total current I_s produced by the absorbed radiation, that is the saturation current is given by

$$I_s = e\,GL, \quad . \quad . \quad . \quad (1)$$

where e is the electronic charge, G is the rate of generation in carriers per second and L is the diffusion length. The expression for the current I_j which flows back through the junction is one well-known in rectifier theory, and may be written

$$I_j = I_0\,(e^{\frac{Ve}{kT}} - 1). \quad . \quad . \quad (2)$$

The net current through the external load is therefore

$$I = I_s - I_j = e\,GL - I_0\,(e^{\frac{Ve}{kT}} - 1). \quad (3)$$

From these equations a formula for efficiency can be derived and then reduced to the approximate expression

$$\eta \approx \frac{k\,T}{e}\,\frac{m}{V_1}\log_e\frac{I_s}{I_0}, \quad . \quad . \quad (4)$$

where $m = \dfrac{I_s}{I_1}$, V_1 is the average incoming particle voltage and I_1 is the bombarding current. The approximation is only valid for $\log_e \dfrac{I_s}{I_0} > 10$.

The current-voltage characteristic as represented by these equations is shown on the right of Fig. 5; since this is not a straight line as in an ohmic device it is evident that the internal resistance of such a generator is a function of the current drawn from it. Experimental current-voltage curves are shown in Fig. 6. The results for three different silicon units are illustrated.

INTERCEPTING THE RADIATION

The geometry of such devices is important if the emitted radiation is to be used efficiently. Radiation from radioactive material is emitted in all directions; it cannot be reflected or refracted, and thus focused, beamed or concentrated, by any known practical method. Hence, for the sake of efficiency, energy converting devices must be designed to intercept as nearly as possible through a solid angle of 4π steradians. Furthermore, in the case of a *p-n* junction device it is important that the radiation be as intense as

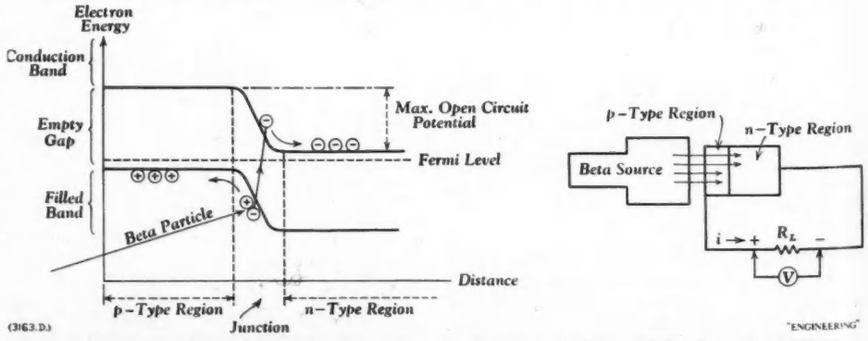


Fig. 4 The semiconductor method employs a *p-n* junction of materials such as silicon or germanium, and by means of the internal electric field transforms radiation into electrical energy. Right: arrangement of system; left: energy-level diagram for *p-n* junction.

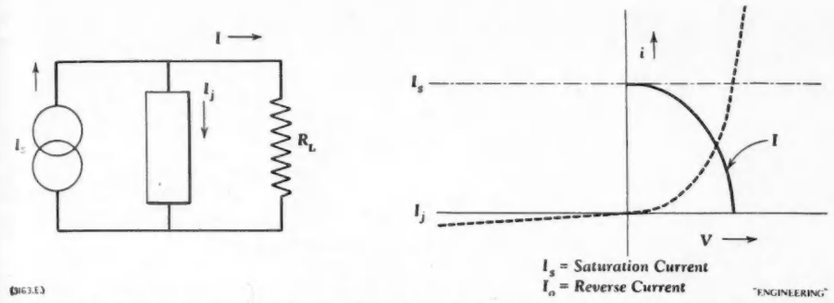


Fig. 5 Equivalent circuit for semiconductor device shown in Fig. 4. Carrier pairs diffuse to the junction, are influenced by the field and move accordingly, so producing a useful current. Right: current-voltage characteristic obtained from equations.

possible, since efficiency improves with increasing radiation intensity. This may be seen from equation (4), since I_s is proportional to radiation density. A practical design incorporating these features appears in Fig. 7, where a layer of radioactive material is shown sandwiched between two *p-n* junctions.

A further geometrical requirement for good efficiency is that the diffusion length of the carriers in the semiconductor, the thickness of the semiconductor, and the depth of penetration of the radiation should all be of the same magnitude. This ensures that the radiation will be completely absorbed, and that the maximum number of produced carriers will reach the junction. This requirement becomes impractical for high-energy uncharged radiation, and is one of the reasons why this method is best suited to charged types or soft electromagnetic radiation.

OSCILLATORS AND RADIO RECEIVERS

The semiconductor device has an important property which enables it to overcome two disadvantages associated with direct charging systems, namely, small current and high internal impedance. This is achieved by high current multiplication in the semiconductor. In other words, each strontium 90-yttrium 90 beta particle that penetrates silicon, for example, will produce on the average about 200,000 new electrons. This high electron multiplication increases the output current by a similar factor and reduces the internal impedance to the same extent. Because of these changes in current and impedance this kind of unit operates on suitably small quantities of radioactive material and has characteristics which make it practical for the operation of electronic equipment, especially where transistors are employed.

Experimental applications of these devices have included their use in oscillators and radio receivers. One, for example, has been employed as a power source for a 1,000 cycle per second oscillator incorporating a single transistor; it was driven by one silicon junction 0·5 cm. in diameter operating in conjunction with 0·05 curies of strontium 90-yttrium 90. In another case, a simple radio broadcast receiver, having a crystal diode detector and three transistor audio-amplifier stages requiring 10 microwatts of power, was operated by eight silicon units of this kind.

"ATOMIC BATTERIES"

The semiconductor method has attracted more attention than any of the others. It can be used to convert the energy of both types of radiation, including visible light, and is the basis of the so-called "atomic batteries" and "solar batteries." With silicon, which is the best material found thus far, outputs of about one-half a volt are obtainable. The current is about 10 microamperes for a 0·3 square centimetre unit when 50 millicuries of strontium 90-yttrium 90 are used.

The best observed efficiency is 3 per cent. However, the current should increase linearly and the efficiency logarithmically with power input according to equations (1) and (4). For example, if 7·5 curies of 100 per cent. radioactive strontium 90-yttrium 90 were used, the power input would be 0·1 watt per square centimetre and equivalent to that obtained from sunlight. The computed values are $I_s = 5$ milliamperes and $\eta = 6{\cdot}6$ per cent. No experiments have been made with this high level of radioactive input power, but the comparable experimental figures for solar energy are $I_s = 8$ milliamperes and $\eta = 5{\cdot}95$ per cent. It should be remembered, however, that operation at this level using silicon and strontium 90-yttrium 90 would result in a very high rate of radiation damage. It would be feasible only if this difficulty were circumvented.

But with all kinds of power source employing radioactive material there still remain problems to be solved before such devices can be considered practical. These are related to: the high cost of radioactive material, radiation shielding, radiation damage and low efficiency.

With regard to cost, the more abundant and cheaper beta materials include strontium 90-yttrium 90, which is 500 dols (approximately £180) per curie, and tritium, which is 100 dols. (£36) per curie. The most abundant and cheapest gamma material is cobalt 60, which costs 50 dols (£18) per curie. U.S. Atomic Energy Commission facilities for the production of these materials are being enlarged, but vast reductions in cost will be necessary before practical applications will be possible for any power range greater than the few microwatts possible at present.

The shielding requirements for strontium 90-yttrium 90 are such that small sources are not possible if the external radiation is to be held below the tolerance level. Low quantum-energy radiation seems to be the logical answer to this difficulty.

The solution of the radiation-damage problems seems to lie also in the use of low qantum-energy radiation, so that the damage threshold is not exceeded. Unfortunately, there is not available at the present time an abundant, cheap, long-life material of this sort. With regard to damage in the case of the semiconductor process, another solution would be the use of a semiconductor material of sufficiently high atomic weight to raise the threshold by a considerable extent.

COST AND EFFICIENCY

Although efficiencies of only a few per cent. have so far been achieved (except for the direct-charging, high-voltage device), higher efficiencies are theoretically obtainable by the use of larger quantities of radioactive material, and here once more the problem of cost and availability arises.

Thus it appears that all the obstacles to a practical larger power source could be overcome by the appearance of a radioactive material which was of low cost, had low quantum energy, and a suitable half-life. Among available isotopes nickel 63 meets all these requirements except that of cost. It emits 0·063 MeV beta radiation, and has a half-life of 85 years; however the present A.E.C. price is is 45 dols (£16) per millicurie. It is to be hoped that attention will be given to this and other materials in the same category.

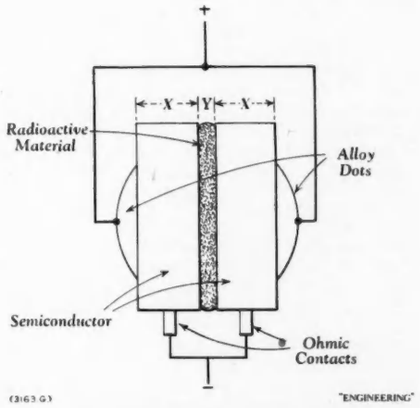


Fig. 7 Since radiation is emitted in all directions conversion devices must be designed to intercept the maximum quantity; radiation must also be as intense as possible. A design in which a layer of radioactive material is sandwiched between two *p-n* junctions incorporates these features.

HIGHER POWERS?

Until this ideal radioactive material is available it appears that commercial radioactive power sources can be considered only for microwatt applications. These might include radiation meters, dosimeters, condenser chargers and leakage compensators, timing circuits, current and voltage reference sources, biasing units and various equipment employing transistors. It is to be expected that the practical energy level for commercial applications will gradually rise as the atomic energy industry develops and radioactive material becomes more plentiful. The ultimate possibilities for commercial uses at higher power levels can be clarified only by future developments.

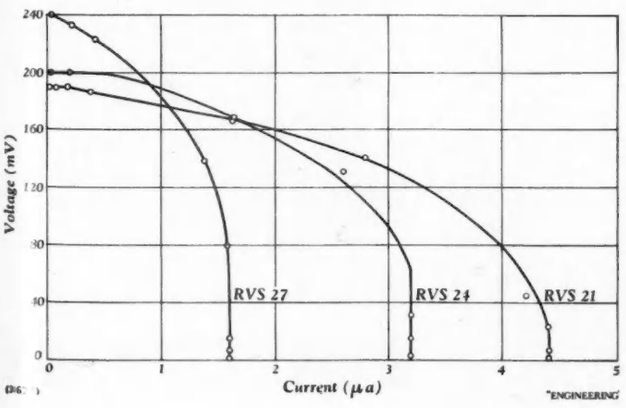


Fig. 6 Experimental current - voltage curves for semiconductor unit; the results for three different silicon units are shown. See Figs. 4 and 5.

ENGINEERING, MARINE AND WELDING EXHIBITION

AND THE FOUNDRY TRADES EXHIBITION OLYMPIA, LONDON SEPTEMBER 1—15

Fifth Article

Since 1906, the style of the exhibition has seen many changes. In earlier years a large number of shipbuilders took part and displayed models of their latest vessels. This year the models were almost completely absent and the emphasis of the Marine section was on machinery, both propulsive and auxiliary, with the internal combustion engine taking a very large share.

Although the exhibition is now closed, this article continues our description of some of the items that were displayed.

HYDRAULIC JACK FOR CONCRETE FORMWORK

Tangyes Limited, Cornwall Works, Smethwick, Birmingham, were exhibiting hydraulic presses, horizontal Diesel engines, various types of centrifugal and other pumps, and industrial heaters suitable for coke, gas or oil burning. Other products on show included a range of "Hydralite" lightweight hydraulic general-purpose lifting jacks, and a new hydraulic jack for use with concrete formwork. This is illustrated in Fig. 52.

This jack, which is known as the "climbing" jack, is designed to raise the formwork as the concrete pouring progresses. It consists of a hydraulic cylinder and piston mounted on a 1 in. diameter high-tensile steel bar, and fitted with lugs to which the formwork is attached by means of a yoke. Two sets of grips are incorporated in the body of the jack, and a detachable key enables them to be opened to place the jack in position on the bar and adjust it up or down as required. When the jack is in the required position and the formwork is attached, the grips are closed and the key is removed. The upper set of grips is attached to the case of the jack and the lower set to the hydraulic piston. Fluid under pressure is supplied from a separate hand-pump, and this causes the piston to tend to move downwards out of the cylinder, which is integral with the case. This movement is, however, prevented by the lower grips, and the cylinder and upper grips move up the bar, carrying the formwork upwards. At the end of the stroke the hydraulic pressure is released, and as the jack cannot move down the bar because of the upper grips, the piston and lower grips move upwards under the influence of return springs. The piston is thus returned to its starting position ready for another lifting stroke. The jack is 5 in. outside diameter and 9½ in. long. It has a normal working load of 2 tons, and a total weight of 40 lb. It moves 1 in. per stroke, and the lifting of the formwork can thus be carried out to the height required by 1-in. increments.

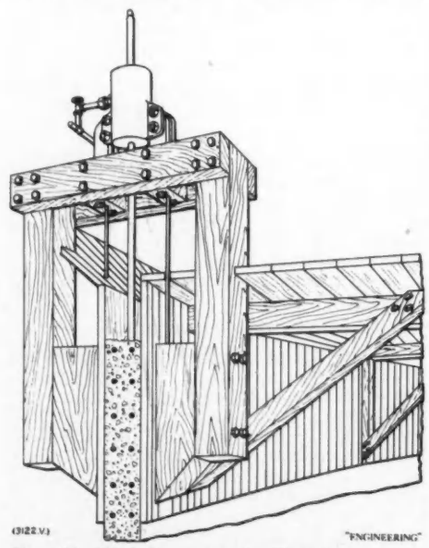


Fig. 52 The Tangye hydraulic climbing jack travels up a vertical steel bar, lifting concrete formwork after it. Any number of jacks can be used simultaneously, and one man can raise the formwork without assistance. Tangyes, Ltd.

Any number of jacks can be used simultaneously as required, connections to the hydraulic hand-pump being made by piping and flexible hose. One man can thus raise the formwork without assistance. Individual control of each jack is provided by means of a stop-valve, which isolates it from the pump. A separate small hand-pump is then coupled to an alternative pressure-connection, and individual adjustments of the jack can be made. If it is desired to move the formwork to prevent sticking, without lifting it in the normal steps, the upper grips are rendered inoperative by a turn of the key. The jack then lifts at each cycle, but returns to its original position when the pressure is released.

LUBRICATING PUMPS

Included in the new equipment exhibited by Tecalemit, Limited, Plymouth, Devon, were an "Impulse" pump, which is available in two forms, adjustable and non-adjustable, and a visible-flow type lubricator which is specially designed to deal with modern oils containing additives.

The Impulse is a single delivery-line unit, which is designed for lubricating heavy-duty machinery operating under arduous conditions. It is illustrated in Fig. 53. It consists essentially of a single-cylinder ratchet-driven pump mounted on the side of a 6-pint rectangular container, which has four bolting lugs for mounting on a flat vertical surface. The container is fitted with a strainer and filler-cap, and has a sight-glass oil-level built into one corner. The pump is driven by a drive-lever which has a roller at its outer extremity, and is operated by an exposed eccentric or other member of suitable form on the machine being lubricated. A spring returns the drive-lever to its starting position as it is released by the driving-member. The lever can operate over an angular range of from 6 deg. to 50 deg. Movement of the drive-lever operates a pair of pawls on a ratchet-wheel, one pawl being longer than the other to give a half-tooth effect and so reduce the minimum working angle of the lever. A second set of pawls prevents reverse movement of the ratchet-wheel which is coupled to a steep-angle cam, which causes the piston of the pump to make its suction stroke the full lift requiring one revolution of the cam. The piston is raised against a spring, which, when the follower passes the nose of the cam, drives it into the cylinder and the delivery-stroke begins. The piston forces the oil through an outlet check-valve, and so into the delivery line, from which branches lead to the bearings being lubricated. The pump delivers 5 c.c. of oil per stroke in the fixed-delivery version, but the total quantity of oil delivered hourly can be adjusted by setting the drive-lever to operate in a larger or smaller angle between the limits of 6 deg. and 50 deg., and so varying the rate of lift of the piston. If an adjustable pump output is essential, a separate version of the lubricator is available. In this the piston is coupled to a cross-head, and it can be adjusted up or down by means of a screwdriver to vary the delivery from 1 c.c. to 5 c.c. per stroke. The ratchet mechanism is completely submerged in the oil being pumped, and is thus kept permanently lubricated.

VISIBLE INDICATORS FOR MODERN OILS

Difficulties are inherent in the well-known glass-tube type of visible flow indicator when using all types of oil, and they may be aggravated when the oil contains an additive. Pressure limitations in the glass tube, changes of temperature affecting the size of the oil "drop," and the fact that minute quantities of water tend to be entrained with the oil so causing the glass to become filled with oil in time, are all possible sources of trouble. To these must be added such difficulties as the fact that oils treated with additives to increase surface-adhesion tend to

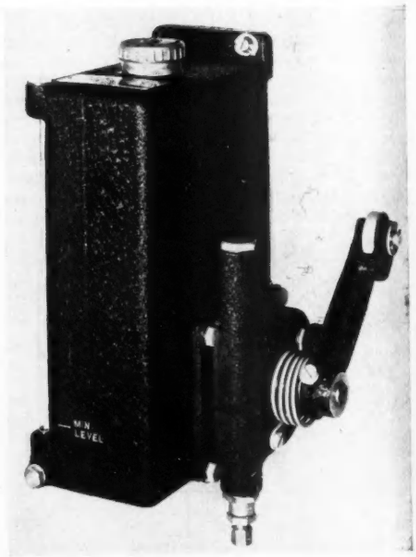


Fig. 53 "Impulse" lubricating pump for machines such as brick presses or concrete-block vibrators, which operate under arduous conditions. Tecalemit, Ltd.

Exhibits Described

Hydraulic Jack for Concrete Formwork *Tangyes, Ltd.*
Lubricating Pumps
Visible Indicators for Modern Oils *Tecalemit, Ltd.*
Cold Repair of Broken Castings *Metalock (Britain), Ltd.*
Double Acting Compressor *Alley and Maclellan (Polmadie), Ltd.*
Automatic Combustion Control System *Ipscol, Ltd.*
Insulation *Chemical and Insulating Co., Ltd.*
Piston Supercharger
Metallic Gland Packing *Wellworthy, Ltd.*
Unit Heaters *Spiral Tube and Components Co., Ltd.*
Remote Control Desk
Grouped Contactor Switchboard *Allen West and Co., Ltd.*
Lapping Machine *Flexibox, Ltd.*
Developments in Ultrasonics *Mullard, Ltd.*
Induction Heaters *Radio Heaters, Ltd.*
Pumps, Compressors and Oil-Burning Equipment *Hamworthy Engineering, Ltd.*
Refrigeration Compressors *York Shipley, Ltd.*
Radiographic Inspection *Teleflex Products, Ltd.*
Nylon Tail for Mooring Lines *British Ropes, Ltd.*
Factory Storage Equipment *Steel Equipment Co., Ltd.*

build up into a large "drop," which eventually smears the sides of the glass tube.

The Tecalemit "falling-drop" automatic lubricator has been designed to overcome these difficulties. It is basically a two-stage pump, which is driven by cams or rockers from the machine being lubricated. The low-pressure stage contains a piston which is driven upwards by whatever form of drive is employed. The first part of the movement seals off the inlet port, and thus traps a quantity of oil. As the piston continues to move upwards the oil acts as a strut, and so moves a secondary piston in the same cylinder until it uncovers the outlet port and allows the oil to pass to a sight-feed tube. The secondary piston is spring-loaded, and as soon as the oil is discharged the spring forces the piston into contact with primary piston. On the return stroke the two pistons travel downwards together, until the secondary piston abuts on the rim of an adjustment sleeve, where it rests, having in the early part of its movement sealed off the outlet port. The primary piston continues its downward movement and creates a void, into which oil flows from the reservoir as soon as the piston uncovers the inlet port. By adjusting the position of the secondary piston in the cylinder the amount of oil pumped per stroke can be varied between zero and 0·1 c.c., or zero and 0·3 c.c., according to the size of the unit. On leaving the sight-glass tube the oil passes to the high-pressure stage of the pump, which is similar to the low-pressure unit except that the secondary piston is not adjustable and the outlet port is in communication with the cylinder above the piston, which is therefore hydraulically balanced by the pressure of delivery. The pump operates at a maximum speed of 300 r.p.m., and can deliver oil at 500 lb. per square inch or more, up to the limit of the cam or rocker-shaft loading. Provision is made for line-priming by means of an independent priming pump, drawing oil from the low-pressure stage and delivering it to the high-pressure output.

COLD REPAIR OF BROKEN CASTINGS

Metalock (Britain), Limited, Grand Buildings, Trafalgar-square, London, W.C.2, had an exhibit showing the application of their metal "stitching" process for the repair of broken or fractured castings. As originally developed, the Metalock process enabled broken or fractured parts of machines or other equipment to be repaired *in situ*, without the application of heat, and without dismantling. Two modifications of this process have now been developed, and all three are available, being used singly or in combination according to circumstances. For metal "stitching" the fracture is firmly clamped and serrated channels are sunk across the crack, the number of channels depending upon the calculated strength required in the finished repair. Specially-shaped "keys" of high-tensile steel are then driven into the serrated channels. The keys have serrations of half-round form to match the half-round holes in the channels, and they are driven home and spread rivet-wise, to lock them in the parent metal. Subsequent layers of keys are added as required, until the surface of the article being repaired is reached. An example is shown in Fig. 54.

This process is the basis of a later development, the "Masterlock," in which a block of high-tensile alloy steel, of the calculated strength required, is sunk into the face of the broken component. The edges of the block are finished with half-holes, which line up with similar half-holes machined into the edges of the hole which is to receive the block. Dowels are driven into the holes formed by the edges of the plate and component, spread, and so locked into both the parent metal and the block. A third development, "Metalace," is also based on the original process. The transverse keys are used in the same way, but by the addition of metal studs, screwed along the line of the crack, between the keys, it is possible to make the repair pressure-tight. Pressures of up to 4,000 lb. per square inch have been dealt with in this way.

Fig. 54 70-ton power press repaired by the "Metalock" and "Masterlock" processes after breakage through overload.

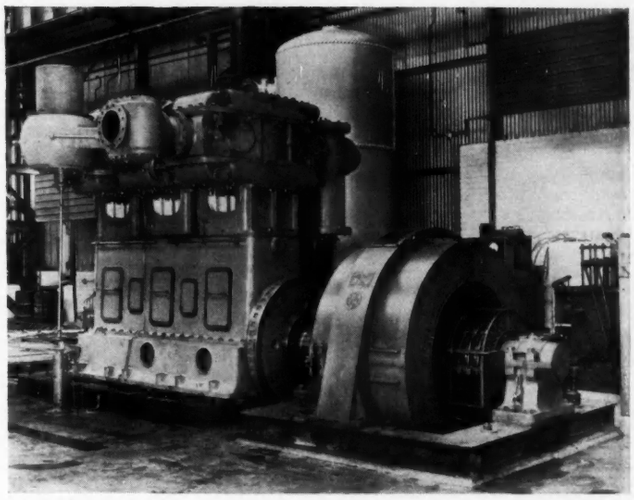


Fig. 55 4,000 cub. ft. three-crank two-stage air compressor. Alley & Maclellan (Polmadie), Ltd.

DOUBLE-ACTING COMPRESSOR

Fig. 55 shows a three-crank air compressor, which was being exhibited by Messrs. Alley and Maclellan (Polmadie), Limited, Glasgow, S.2. As will be seen, this is of the vertical type, the cross-head and cylinders being entirely isolated from the crank case. The main advantages of this design are that piston side thrust on the cylinder wall is eliminated and oil leakage from the crank case into the air supply is prevented. In addition, the sets are very compact so that they can be installed in small buildings.

The machines are of the two-stage double-acting type, the cylinder areas being calculated to ensure a balanced distribution of the operating forces. Intercooling is provided between the stages by an intercooler of the contra-flow design, thus ensuring efficient heat transfer from air to water. The cylinders are also provided with water jackets to assist in obtaining the closest possible approach to isothermal compression.

The model shown is electrically driven by a 725 b.h.p. motor and is capable of delivering 4,000 cub. ft. of free air per minute up to a working pressure of 80 lb. per square inch when running at 333 r.p.m.

AUTOMATIC COMBUSTION CONTROL SYSTEM

On the stand of the Chemical and Insulating Group of Companies one of the member firms, Ipscol Limited, Shipyard Estate, Hythe, near Southampton, were showing an automatic combustion control system that they are manufacturing under licence from A. W. Cash Company, Decatur, Illinois, U.S.A.

This system maintains constant steam pressure, correct fuel/air ratio, and constant combustion-chamber draught. It can be operated by compressed air, oil or water pressure. Its robust mechanical construction ensures long service without maintenance troubles.

The equipment comprises a master controller type 100, which continuously measures variations in steam pressure and adjusts the firing rate to maintain this pressure constant within predetermined limits. At the same time, the type 100 controller readjusts the setting of an air-flow controller known as the type 95, which through continuous adjustment of the forced-draught damper maintains a sensibly correct fuel/air ratio throughout the boiler load change. A separate furnace draught controller, type 90, maintains balanced draught conditions within the combustion chamber by continuous adjust-

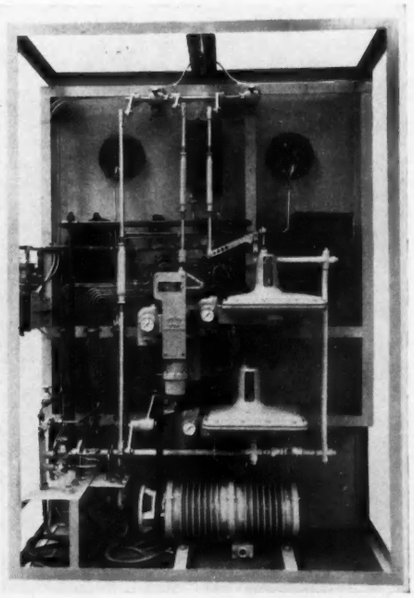


Fig. 56 Ipscol/Cash automatic combustion control system, mounted at rear of a boiler instrument panel. Ipscol, Ltd.

ment of the induced draught or chimney damper. Operation of these controls is normally carried out by an Ipscol oil-pump circulating unit, but clean compressed air or mains water may be used. Fig. 56 shows the compact arrangement of the controllers mounted at the rear of a boiler instrument panel.

In the case of oil-fired installations, the induction regulator controlling the stoker speed would be replaced by a special impulse-loading valve coupled to the master steam-pressure controller. This loading valve would transmit a variable-impulse signal to the regulating valve installed in the oil-burner ring main, and thus adjust the rate of firing to maintain constant steam-pressure conditions. Adjustment of the air flow and the furnace draught would be unchanged.

INSULATION

The parent company of the group, the Chemical and Insulating Company, Limited, Darlington, County Durham, were exhibiting various types of magnesite insulating materials. The other group members' exhibits were as follows: the Darlington Insulation Company, Limited, 38 Great North-road, Newcastle-upon-Tyne, 2, a contracting organisation, were exhibiting thermal and sound-insulation systems, showing the build-up and thicknesses of the various materials used. The British Refrasil Company, Limited, Stillington Works, Stillington, County Durham, manufacturers of pure-silica fibre, were showing insulating blankets for jet engines comprising a thickness of silica wool enclosed in a stainless-steel envelope. S. T. Taylor and Sons, Limited, Kingsway, Team Valley Trading Estate, Gateshead-on-Tyne, 11, sheet-metal workers and manufacturers of special machinery, were showing photographs of some of the more interesting work that they have carried out recently.

PISTON SUPERCHARGER

The items on the stand of Wellworthy, Limited, Lymington, Hampshire included a large selection of pistons and rings, among them being the Alfin light alloy piston which has an austenitic iron insert molecularly bonded to the body. Cylinder liners and other engine parts were also displayed.

One of the larger items was a prototype of the Ricardo-Wellworthy supercharger designed for all types of Diesel engine. The mechanism is shown diagrammatically in Fig. 57 and in an illustration of a sectioned model in Fig 58. This machine was developed by Ricardo and Company, Engineers (1927), Limited, Bridge Works, Shoreham-by-Sea, Sussex, and is to be produced commercially by Wellworthy.

The compressor has two banks of seven double-acting pistons arranged in a circle around the rotary valve which controls both inlet and outlet. A Z-crank or wobble-plate, which does not itself rotate, drives all fourteen pistons. Owing to the symmetrical arrangement, the only internal out-of-balance forces are those connected with the anchoring of the wobble-plate and these are balanced out in the final machine. The drive from the engine is to one end of the supercharger.

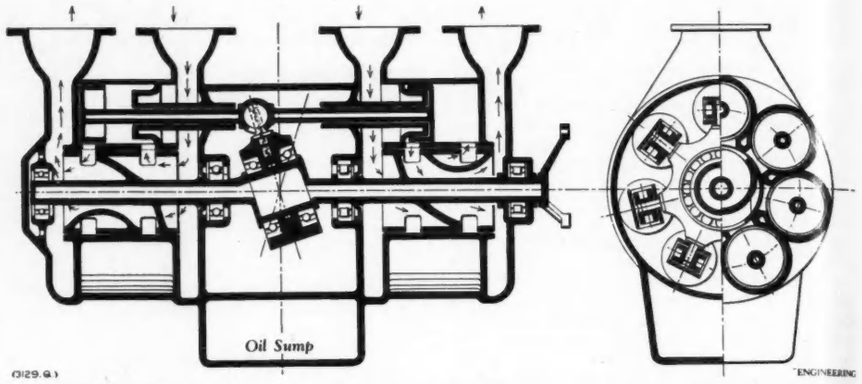


Fig. 57 The fourteen pistons of the supercharger are driven by a central wobble-plate. Rotary valves control the air flow, the direction of which is indicated in this drawing by the arrows. Wellworthy, Ltd.

The pistons, rotary valves and the main casting are all of light alloy, rendered possible because there is clearance between all these parts. The pistons are centralised in the cylinders by the long piston-rod guides, and labyrinth grooves form the seal. The clearances between the pistons and the cylinder walls and between the rotary valve and the casing also obviate the need for lubrication of these parts and so help to produce oil-free air. Large ports and small clearance volumes assist in the efficiency. The delivery pressure can be kept reasonably constant (within a given range) independent of the speed of rotation by automatic action of the rotary valves, which can move axially to vary the time of port opening and closing.

Tests on prototypes have shown that adiabatic efficiencies greater than 70 per cent. can regularly be obtained and that the supercharger can operate satisfactorily against pressures up to 30 in. of mercury, though the normal range would be between 10 and 20 in. It has the great advantage that the full swept volume is delivered at low speeds, enabling the engine torque to be greatly improved. The normal driving speed of the supercharger is between 1½ and 2 times the engine speed. The weight of the 14-cylinder model is about 80 lb. and the swept volume 3·6 litres. This size is suitable for use with any Diesel engine which has a swept volume between 5 and 9 litres—a range which includes the majority of automotive engines now being made. The supercharger dimensions are approximately 17 in. long by 12 in. in diameter; these, as well as the weight, compare favourably with most other types now on the market. Moreover, it is very quiet in operation and cannot be heard above the ordinary engine noise. Although there are more moving parts than in the Root's type, many of them are identical and all can be machined to standard tolerances. A single-ended (seven cylinder) version is also made.

METALLIC GLAND PACKING

Also being shown by Wellworthy's was a metallic gland packing for reciprocating shafts. This has been evolved from the idea of a piston ring, and is made up from four parts. An L-section cast-iron carrier ring has within it an inwardly-contracting spring ring which grips two sealing rings each made of three segments. These last are available in cast-iron, bronze, tin-aluminium alloy, carbon or gold seal to suit the material of the shaft and the application. A complete shaft-seal is made up of from four to eight of these assemblies, which can be fitted by semi-skilled labour and require no after adjustment. All sizes are manufactured, and the packing is claimed to have proved completely satisfactory in service.

UNIT HEATERS

Among the exhibits of the Spiral Tube and Components Company, Limited, Osmaston Park-road, Derby, were two new unit heaters, suitable for boardrooms, offices, etc., known as the Spiraluxe Mark II, one all-electric, and the other for steam operation but incorporating an electrically-driven fan. The electrical heater, in 2 kW and 3 kW sizes, is available either for wall mounting or as a portable unit. In both models, the fan can be run independently in hot weather. An automatic thermal cut-out is incorporated to safeguard the elements in the event of fan stoppage.

They were also showing their Air-Towel for face and hand-drying by means of an electrically-driven centrifugal fan, utilising an existing steam-heating system; and oil and water coolers for use on traction and stationary Diesel engines.

REMOTE CONTROL DESK

Messrs. Allen West and Company, Limited, Brighton 7, were showing the remote-control desk illustrated in Fig. 59. This is a replica of a number of similar equipments which have been installed by Messrs. F. N. Wheeler and Company, Limited, in the works of General Refractories, Limited, Sheffield. The mechanical handling installation operated from this desk comprises conveyors, vibrating feeders, crushing plant and storage hoppers with primary and secondary flow lines. The main equipment consists of grouped contactor-pattern multi-motor switchboards and desks, each placed to provide centralised control of the different stages in the production process.

Electrical interlocking between the various devices is an important feature in the design of the gear. For example, the flow of materials is fully enclosed, any dust arising being extracted

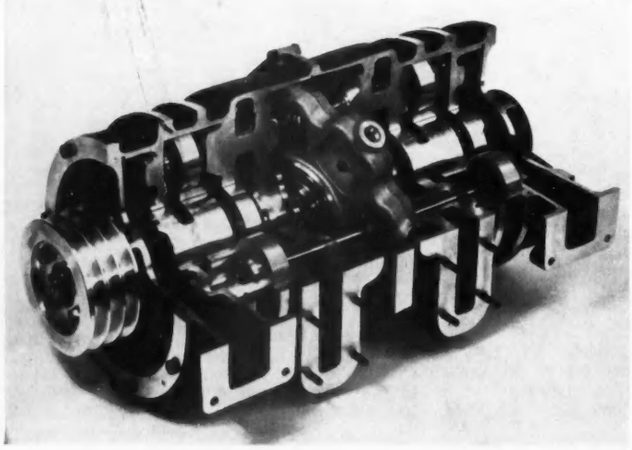


Fig. 58 With a swept volume of 3·6 litres, the Ricardo - Wellworthy supercharger is suitable for all Diesel engines within the range 5 to 9 litres. Wellworthy, Ltd.

Fig. 59 Remote-control desk for mechanical handling installation. Allen West & Co. Ltd.

by exhaust fans and recovered by bag filters. The arrangement is therefore such that no other drives can be started until the fans are running and thereafter the flow line is started in reverse and in sequence to prevent the materials piling up.

The actual desk shown is to be used for controlling that part of the system which deals with the raw material coming from storage and transmits it by alternative routes along vibratory feeders to an inspection conveyor. It passes thence through a Pegson primary crusher to four storage bins, any one of which may be selected by operating a switch on the desk. For certain materials there is a secondary route over which material can be conveyed from the inspection conveyor direct to separate storage. When the required route has been selected and the various motors have been started in the correct sequence, coloured lamps are lighted on a mimic diagram to show the drives that are actually running. Finally, a load is dispatched by pressing a push-button switch.

GROUPED CONTACTOR SWITCHBOARD

The same firm were exhibiting a grouped contactor switchboard, a typical example of which is illustrated in Fig. 60. This is similar to the board which is to be installed on the new Cunard vessel Carinthia and comprises automatic contactor starters for such engine-room auxiliaries as feed pumps, oil pressure pumps and compressors.

Compared with separate enclosed-type starters installed adjacent to the machinery in various parts of the engine room this type of switchboard has the advantage of saving space, simplifying the cable runs and facilitating inspection and maintenance. Each starter on the switchboard has its own isolating switch and can be made "dead" without interfering with any of the others. All the starters are supplied from main copper busbars, which run the length of the rear of the switchboard.

LAPPING MACHINE

The Mark IV lapping machine was one of the principal objects of interest on the stand of Flexibox Limited, Nash-road, Manchester, 17. It is a self-contained machine for the precision lapping of a wide range of articles from soft non-metallic materials to very hard metals. It has a rotary lapping plate of 21 in. diameter, giving loadings of 99 items of maximum diameter $\frac{3}{4}$ in., 21 of maximum diameter $2\frac{1}{4}$ in., or three of maximum diameter $7\frac{3}{4}$ in.

The lapping plate is driven by a 2 h.p. 3 phase motor through a reduction gearbox at 65 r.p.m. In general, articles contained by a circle of up to $7\frac{3}{4}$ in. diameter can be accommodated within each of the three wear rings which can be seen in Fig. 61 on top of the lapping plate. The parts to be lapped are held in three workholders which run inside the wear rings. The work, workholders and wear rings rotate due to frictional drag. Both the plate and the wear rings are made from close-grained cast iron so that the surface of the plate is maintained smooth and flat.

A special feature of the machine is its automatic control of the lapping plate flatness. A high degree of control is obtained by the provision of a spring-loaded roller which bears on one of the wear rings. When no load is applied there is a tendency for the plate to become concave. Application of the load balances this tendency. This control device continuously conditions the lapping plate during operation, and the day-to-day running of the machine can therefore be left in the hands of unskilled personnel.

Abrasive compound is automatically fed at a controlled rate to the lapping plate. This compound is made up of a suitable abrasive powder held in suspension in a non-fluid oil vehicle. The powder and vehicle are put separately into a mixing tank mounted on the table of the machine, and by means of a small power-driven stirrer the suspension is kept continuously mixed. It is fed via a control valve to the lapping plate where it is spread into an even film by the wear rings. A drip tray is provided under the lapping plate and worn abrasive is drained away to a waste container. The lapping plate is covered against dirt and other foreign matter by a transparent plastics hood which opens to permit the work to be handled. It is claimed that a surface finish of 2 micro-inches r.m.s. can be obtained on steel and similar materials.

In addition to the lapping machine Flexibox demonstrated their range of mechanical seals for rotary shafts, one of which was the RRTCQ balanced mechanical seal. This is fitted with parts made from PTFE for maximum resistance to acids and alkalis, and it is designed to prevent shaft leakage at high temperatures and pressures. It can deal with corrosive fluids at temperatures up to 480 deg. F. and pressures up to 800 lb. per square inch gauge. An unbalanced version, type RTC, for dealing with stuffing box pressures up to 100 lb. per square inch gauge, was also shown.

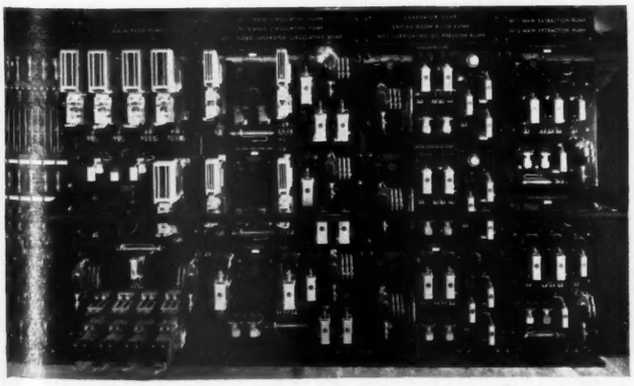


Fig. 60 Grouped contactor switchboard for controlling ship's auxiliaries. Allen West & Co., Ltd.

Fig. 61 This lapping machine has a rotary plate diameter of 21 in. and is designed for use by relatively unskilled workers. The plastic hood prevents ingress of foreign matter while the machine is working. Flexibox Ltd.

DEVELOPMENTS IN ULTRASONICS

Industry continues to find new uses for ultrasonic energy, and equipment for its industrial application was shown on the stand of Mullard Limited, Century House, Shaftesbury-avenue, London, W.C.2. The most interesting exhibit was the 2 kW ultrasonic machine tool, shown in Fig. 62, which has been designed for carrying out all normal production machining processes on hard and brittle substances. It is capable of reliable operation by those used to working with normal precision machine tools such as milling machines.

The 2 kW ultrasonic tool is a prototype equipment which has been developed at Mullard's research laboratories. Standard generators and transducers are employed, and production equipments can therefore be made using these. One such equipment is now under joint development by Mullard's and Kerry's (Great Britain), Limited. The power input to the drill is eight times greater than the input to the drill type E.7690 which is now in production, and as a result the cutting speed of deep holes has been much increased.

A second exhibit was a completely mechanised ultrasonic cleaning plant, again built in conjunction with Kerry's Limited. This type of equipment was described in ENGINEERING for August 6, 1954 (vol. 178, page 172), and is suitable for removing loose contamination from such engineered parts as ball races and hydraulic valve components. A similar plant, powered by a low-frequency ultrasonic generator, can be used to remove tenacious films from components. Since these equipments can clean articles rapidly and thoroughly and also deliver them dry, they can be incorporated in assembly lines.

In the demonstration, an input conveyor belt took the parts to be cleaned to an automatic basket-loading device, which loaded and passed a 6 in. by 4 in. basket on to the main chain conveyor every 15 seconds. The baskets passed through three tanks in succession: first, through a pre-wash tank containing trichlorethylene, then through an ultrasonic cleaning bath powered by a 2 kW ultrasonic generator, and finally through a hot vapour zone for drying. The baskets were then automatically transferred to a belt conveyor at the output end.

An important part of the apparatus is a system

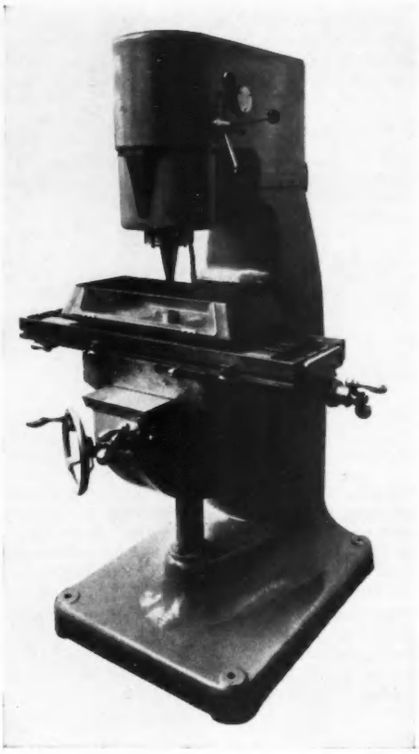


Fig. 62 An experimental 2 kW ultrasonic machine tool for machining hard and brittle materials. The cutting is done by abrasive particles fed to the tool tip. Mullard Ltd.

for continuously filtering and purifying the cleaning fluid. Ferrous particles are removed by a magnetic filter, while gauze, ceramic, and paper filters remove particles down to 1 micron in diameter. Oil and grease are removed by a continuous distillation process. This automatic cleaning plant is only one example of the application of ultrasonics to industrial cleaning. Where small quantities of parts have to be cleaned, less elaborate equipment will suffice, such as the small hand-fed ultrasonic cleaning tank which was demonstrated alongside the main exhibit. Fields of application of this method of cleaning include the watch and clock industry, die-making, radio valves, precision instruments, and gyro-engineering components.

Other exhibits on this stand were the 2 kW low-frequency ultrasonic generator type E7696, which was described in ENGINEERING for August 19, 1955 (vol. 180, page 243), and the ultrasonic soldering iron for aluminium and light alloys.

INDUCTION HEATERS

Radio Heaters, Limited, Eastheath-avenue, Wokingham, Berkshire, were showing several induction heating equipments, some of which have already been described in ENGINEERING (vol. 178, page 182, 1954 and vol. 179, page 302, 1955). Two, however, were on view for the first time. These were the Radyne bench equipment and a 25 kW unit. There was also on show a separate water re-circulating unit, capable of dissipating 20 kW.

The bench equipment, which is shown in Fig. 63, occupies an area of only 2 ft. 7 in. by 1 ft. 10 in. The flexible lead allows the operator a considerable scope for work. The equipment is housed in a cast aluminium casing capable of withstanding much hard use. A special high-impedance output transformer is available for flexible lead and also for vacuum work. The model shown in the illustration has a water re-circulator for cooling the lead, which is 7 ft. long. The unit having a rating of 3 kW is capable of handling all smaller soldering and brazing work, and is believed to be the first bench-type set available in this country, and the only one with fully variable power output matching in the world.

The transformer provides for a heat control variable over a range of 20 to 1, which allows accurate work to be carried out. When a flexible lead is used, the heat output is somewhat down but is still ample for most silver-soldering and brazing requirements and for de-gassing cotton-reel carbon anodes at 1,160 deg. C. in tubes with rated dissipations of 300 watts. The full load input is 5·5 kW and the standby requirement one tenth of this.

Controls on the set include mains switch and operating buttons, together with a socket for control by foot-switch or remote buttons. A process timer can also be fitted using this socket. The control for varying the heat output is mounted on the right. It is possible to mount both heater and water circulator on a trolley, so forming a mobile unit. If the water circulation fails, the unit is automatically switched off. When not used with a recirculator, water at a pressure of 30 lb. per square inch minimum is required at a rate of $\frac{1}{2}$ gallon per minute. A smaller heating unit with an output of 1 kW is also made.

The second of the new Radyne units on show was a completely self-contained 25 kW set. The floor space required is 4 ft. wide by 3 ft. deep, and this includes the water cooling system which is built into the equipment. There is a fully variable power output matching control and a wide range of accessories is available. It was demonstrated heating a 2 in. length of 1 in. diameter steel bar—the bar taking between 15 and 20 seconds to reach red heat.

PUMPS, COMPRESSORS AND OIL-BURNING EQUIPMENT

Among the pumps exhibited by Hamworthy Engineering, Limited, Poole, Dorset, was the vertical centrifugal pump illustrated in Fig. 64, the demonstration model being sectioned and fitted with Perspex windows to show the action of the constant-running primer working in conjunction with the air-separator chamber; air was admitted at intervals into the suction system in a manner which simulated bilge-pumping conditions on board ship. The pump has a capacity of 200 gallons per minute at 1,420 r.p.m. against a total head of 45 ft.; other pumps in the same range have deliveries up to 3,000 gallons per minute.

Hamworthy also showed an example of their

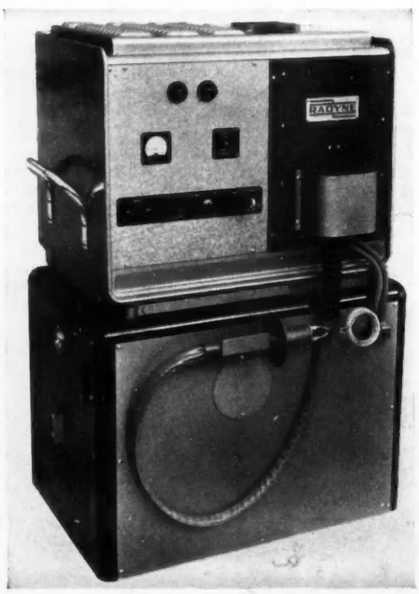


Fig. 63 Bench induction heater with fully variable power output matching. Rated at 3 kW, it is shown mounted on a water circulating unit. Radio Heaters Ltd.

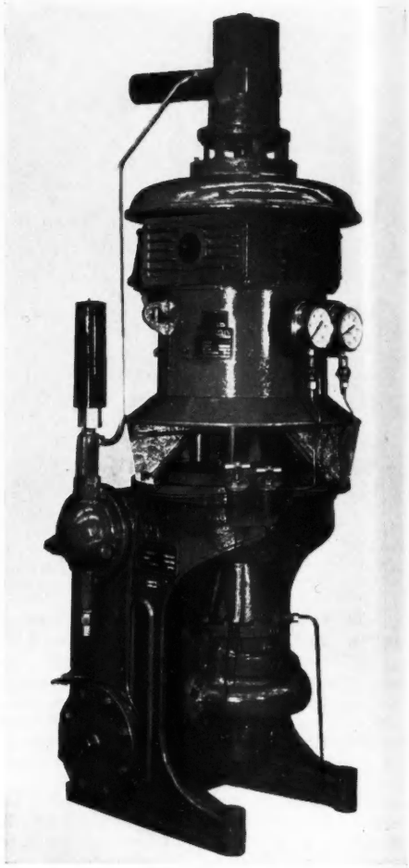


Fig. 64 200 gal. per min. vertical centrifugal pump with constant-running primer. Hamworthy Engineering, Ltd.

series of vertical gear pumps of capacities ranging from 10 to 300 tons per hour against pressures up to 100 lb. per square inch, and which are particularly suitable for fixed lubrication, piston oil cooling, and light or heavy fuel-oil transfer duties; an air-cooled two-stage compressor for pressures up to 200 lb. per square inch; a two-stage water-cooled compressor for main starting duties on marine Diesel engines, for pressures up to 450 lb. per square inch; and a small tandem two-stage compressor for emergency and auxiliary starting air, with a maximum rating of 15·7 cub. ft. per minute at 1,500 r.p.m. against a working pressure of 450 lb. per square inch.

The oil-burning equipment shown by Hamworthy included burners for Scotch Marine and other shell-type boilers, and a rotary burner suitable for the heavier grades of fuel oil, in capacities from 4 to 120 gallons per hour; and a 1,500 lb. per hour duplex pumping and heating set suitable for all liquid fuels, including Bunker C grades and creosote/pitch mixtures; this set is one of a range with capacities from 250 to 40,000 lb. per hour.

REFRIGERATION COMPRESSORS

York Shipley, Limited, North Circular-road, London, N.W.2, exhibiting for the first time at this exhibition, were showing a range of compressors and refrigerating equipment. Among the items was the Yorkmatic air-conditioning set which is driven by a $\frac{1}{4}$ h.p. electric motor and has both motor and compressor in an hermetically-sealed case. No jointing material is used in the compressor which relies on metal-to-metal contact for sealing. Another feature is that the motor is overhung from the compressor shaft.

Two models of the V/W series of compressors were on display—one with four and the other with 16 cylinders. The full range is 4, 6, 8, 12

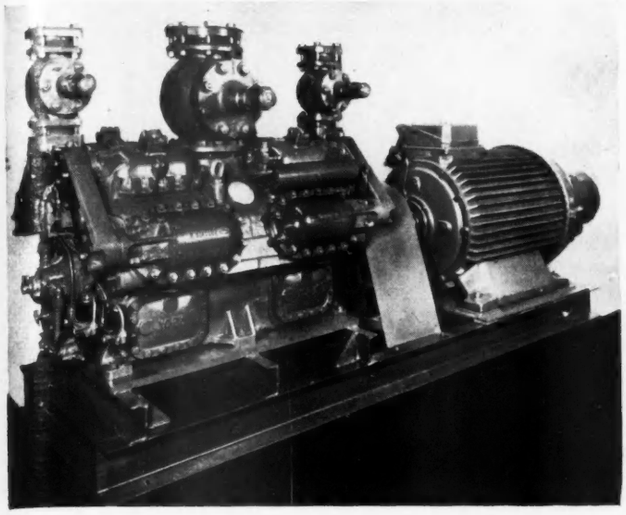


Fig. 65 (left) Designed for use on board ship, this 16 cylinder compressor is light in weight and requires low headroom. York Shipley, Ltd.

and 16 cylinders with powers from 15 to 150 h.p. The range is designed to have all parts standard as far as possible so that the minimum number of spares need be carried, and also for ease of servicing. As this range is intended for shipboard use, these two points, together with compactness and lightness, are of importance. As an example, the 16 cylinder model complete with motor weighs approximately 6,100 lb. and is about 106 in. long by 35 in. wide by 58 in. high. It is illustrated in Fig. 65.

As will be seen from the illustration, the cylinders are arranged in two banks around the crankshaft, which has only two throws, pairs of pistons being in opposition to give balance. Pistons and valves are accessible by removing the cover plates, and the cylinder liners can be withdrawn by hand. All oil pipes are external and can be separately removed for inspection or cleaning. The set starts up with only one quarter of the pistons under compression, so that motors with low starting torque can be used and elaborate starting gear is avoided. As the oil pressure in the lubricating system builds up, spring-loaded pistons in the cylinder heads are moved and these allow the inlet valves of the remaining cylinders to seat and become operative, thereby bringing the compressor up to full load. This control of the inlet valves can be made automatic so that the compressor unloads when full pressure is reached, but the motor remains running. Sealed safety valves are fitted to each cylinder to prevent damage by accidental overload. Either automatic or manual starting can be arranged.

RADIOGRAPHIC INSPECTION

In addition to examples of their conveyors and remote control equipment, Teleflex Products, Limited, Chadwell Heath, Essex, were showing their Pantatron units for gamma radiography which were introduced last year. These are made in several sizes, one of which is illustrated in Fig. 66. A particular feature is that two or three sources can be contained in the same unit and can be selected at will.

The containers for the sources are pencil shaped and fully shielded. They are fitted in a revolving housing which forms the projection at the left-hand end of the unit in the illustration. This housing can be locked in the closed (safe) position and must be unlocked before a source can be exposed. In operation the housing is unlocked and revolved till the required source is in position. The container is then opened by a lever, and the operator can retire to a position of safety taking with him the remote-control box. Turning the handle on this box causes the source container to be pushed through the unit and along the tube at the right until the source projects at the end. This tube extension may be 4 ft. long or more, providing it is properly supported. The required length can be obtained by adding sections. When exposed at the end of the tube, the source has almost a complete sphere of influence, except only for the cone shielded by the tube itself. Therefore, complete circumferential radiographs can be made, or alternatively, the items to be inspected can be ranged around the end of the tube and a large number can be done simultaneously. After the exposure is complete, the source is drawn back into the housing by the remote control, and the operator should lock the container before removing the exposed film. The action of locking is the guarantee that the source is "safe". The unit is portable and can be tilted into any convenient angle. A dial on the remote control unit shows the distance the source has been moved along the tube.

NYLON TAIL FOR MOORING LINES

Shown for the first time on the stand of British Ropes Limited, Doncaster, was the Viking nylon tail combination with fibre rope, illustrated in Fig. 67. This combination, designed to give greater security for vessels moored or docked under hazardous conditions, comprises a six-fathom length of nylon rope incorporated into the shore end of mooring lines, to which it gives additional elasticity and assists in passing the line to the shore or tug. When the manila portion of the line wears, it can be cut clear of the eye splice in the nylon tail, turned end for end, and respliced. The Viking nylon tail combination has been tried out with favourable results by many British shipping lines and tanker companies.

In addition to examples of their hemp, nylon and Terylene marine ropes, British Ropes Limited also exhibited their Blue Strand preformed wire rope, which is claimed to have a longer life under bending loads since the wires and strands are free from residual stress and the load is more equally shared between the strands. The rope is also more easily spliced and readily installed.

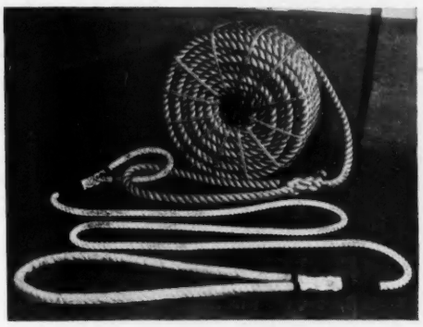


Fig. 67 By means of a nylon "tail" the life of a manila rope can be increased and it can be handled more easily. British Ropes Ltd.

FACTORY STORAGE EQUIPMENT

The range of factory storage equipment exhibited by the Steel Equipment Company, Limited, Greets Green, West Bromwich, Staffordshire, included some new items which were being shown for the first time.

The "Boxrax" storage system consists of a stacking steel box which is available in three sizes and can be stacked vertically, or used in conjunction with standard shelf-frames for compartment storage. For temporary storage of components in production, stacks of any required height and area can be built up quickly by stacking the boxes one on top of another, the top of each box being set back and the bottom recessed to act as a spigot and socket. For permanent storage the same boxes can be used with adjustable shelving to form units of any size required. These can be of the closed or open type, and can incorporate shelving drawers for small components as well as shelves for the standard boxes. They can also be arranged to hold two different sizes of standard box, and can have open shelves in addition.

Another new item was the steel nesting and stacking pan. This is of rectangular form, with two ends sloping outwards. Folding handles are fitted to these ends, and when folded inwards they form supports for another pan to be stacked on top. In this way a stack of any required height can be built up, the outward-sloping ends enabling the contents of a pan to be seen at whatever point in the stack it may be. When the handles are folded outwards they can be used for carrying the pan. In this position they also allow one pan to nest inside another, and when not in use the pans can therefore be nested in a small space.

To be continued

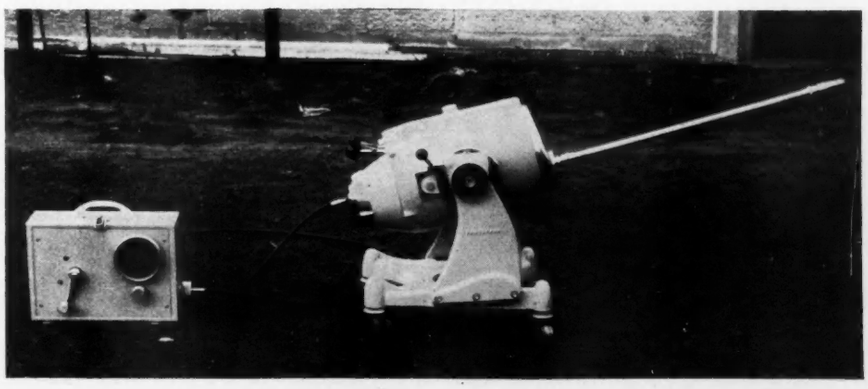


Fig. 66 Radiograph unit containing alternative sources. On the left is the remote-control box, by means of which the source is exposed at the end of the projecting tube. Teleflex Products, Ltd.

AUXILIARY OIL FIRING APPLIED TO PULVERISED FUEL BOILERS

RAPID STEAM-RAISING WITHOUT OVERHEATING

The operation of the pulverised fuel boilers which are now being installed in the majority of thermal power stations can be improved by the use of auxiliary oil firing. This enables the coal to be rapidly ignited and the steam pressure to be raised without overheating the superheater elements—points which are important in two-shift stations, where it is necessary that the boilers should take up the load without delay. The stabilisation of combustion is also facilitated, thus reducing the risk of flame failure or explosion, owing to temporary bad coal conditions.

To fulfil these requirements Fuel Firing, Limited, Woodley, Reading, Berkshire, developed a prototype "initiator" which, with the collaboration of the Southern Division of the Central Electricity Authority and Messrs. Charrington Gardner Locket (London), Limited, was installed on one of the 200,000 lb. boilers in Earley power station. This prototype was designed to work on heavy fuel oil of 960 second Redwood No. 1 viscosity, so as to reduce the running cost; and to operate intermittently and rapidly. It was made retractable and was thus protected from the heat when not in use. Fully automatic control with all the necessary safety features was provided, and to ensure operating reliability and minimum maintenance it was designed to withstand the temperatures and differential expansion conditions in the hottest part of the furnace.

INITIATOR DESIGN

As a result of experience certain modifications in the original design were introduced and a front view of the initiators now installed at Earley, showing the initiator in the firing position and sealed off with the closing plate, is given in Fig. 1. Fig. 2 is a side elevation of the initiator, the various parts mentioned in the following description being given in the legend. It consists of a chassis which is mounted on a shaft carried in two bearings on the main frame of the boiler. It can thus be rotated by a pneumatic cylinder *a* round a horizontal axis into and out of the furnace. It also carries self-cooling sealing plates, one of which, *b*, closes the furnace port when the equipment is retracted, while another *c* ensures close fitting between it and the port when it is in the operating position.

The chassis itself carries an atomiser *d* of the gas-turbine type, consisting of three precision ground plates. It is designed to give a finely divided spray of definite shape and consistency, thus ensuring the correct quantitative admixture of oil and air at the correct velocity and bringing about complete combustion.

AIR SUPPLY

Air for combustion is supplied from a two-stage fan, which is integral with the initiator and is driven by a totally-enclosed surface-cooled induction motor. It discharges into a duct which is coaxial with the burner trunnions and is arranged so that the air seal is effective with the burner in any position. To ensure complete combustion the air supply is divided into three parts—primary, secondary and tertiary. The primary air is used to cool the atomiser, round the periphery of which it is introduced, and thus to prevent the building up of carbon deposits and to reduce cleaning. The secondary air is supplied through a series of vanes *e* which are arranged round the periphery of the burner and by setting up a swirling motion create the turbulence necessary for correct mixing. The tertiary air is led in through an annulus surrounding the secondary air to shape the flame and to complete the combustion. The whole unit is self-cooling during operation, even when the main coal burners are working on full load.

The igniter *f* is enclosed in a housing *g* which is mounted directly above the main air tube. Its front is protected by a hinged door *h* and it is cooled by air drawn from the fan ducting. When required for ignition it is projected forward into the fuel-oil spray by compressed air supplied from the cylinder *i*. After about six seconds it is then withdrawn behind the protecting door. Originally high-tension ignition was fitted, but when this was found to be unreliable it was replaced by a 10-volt igniter, which operates at the same speed and requires no attention for three months.

OPERATING PROCEDURE FOR STARTING

The initiator is operated from a panel on the main boiler control board, on which "start" and "stop" buttons, indicator lamps and a four-position rotary selector switch are mounted. When this switch is in the twelve o'clock position the supply is cut off from the initiator. In the three o'clock position the initiator is put under the control of the "stop" and "start" buttons, while in the six o'clock position it is under the influence of the monitor and lock-out viewers, described later in this article, for combustion stability control.

The nine o'clock position is to start the fan when the initiator is being run manually. On pressing the "start" button a solenoid is energised, thus opening a valve and admitting compressed air to the cylinder *a*, which swings the initiator into position. This movement also operates an auxiliary switch, which energises a second solenoid through a time-delay relay, so that another valve is opened and compressed air is admitted to the cylinder *i* driving the igniter. The result is that when the initiater is about 30 deg. to the horizontal the igniter is pushed forward from its housing and its circuit closed, so that it is instantaneously raised to white heat.

As the initiator takes up its operating position in the furnace it mechanically actuates two high-pressure cocks, which are connected in series, and thus causes oil to be admitted to the atomiser. Ignition then occurs, the flame being normally established within two seconds of the "start" button being pressed, as is shown by an "igniter in" signal on the control board. This is followed by the "igniter out" signal when full retraction has occurred after about six seconds. The flame energises a photo-electric cell with the result that a "flame-in" lamp is lighted on the control board. An amplified signal from the same cell is also transmitted to the fan motor, which is thus started up automatically and operates a switch so that a "fan running" indication is shown on the control board.

In the event of a flame not being established the time-delay relay mentioned above, operating in conjunction with an electronic device on the closing plate, causes the initiator to swing out of the furnace and a "flame out" indication to be given on the control board. When this has occurred the initiator cannot be operated until the relay has been re-set by pressing the "shut down" button. Normally the igniter remains in operation until the "stop" button has been pressed. It also shuts down automatically and is withdrawn from the furnace if the electricity or compressed air supplies fail or if the igniter fails during operation.

SOME TEST RESULTS

As has already been mentioned, heavy fuel oil is used in this equipment. That this oil can be burned in a fully-cooled furnace without risk of contamination due to unburnt oil or carbon deposits is shown by the results of tests which were made by Fuel Firing, Limited, in collaboration with the Southern Division of the Central Electricity Authority. In another series of tests the Superheater Company installed thermocouples, connected to a switch-point-continuous recorder, in selected positions across the width of the boiler and, as shown in Fig. 3, at no time did the metal temperature rise to a dangerous point. This, it is claimed, indicates that the superheater elements are safeguarded from overheating until the main firing equipment is operating, a result which is due to the heat release of the initiators being pre-determined.

It may also be noted that when the steam pressure has been raised by the initiators hot air can be supplied to the pulverisers, thus simplifying the starting of the coal preparation plant and improving the initial combustion. In fact, it is only necessary to start one induced

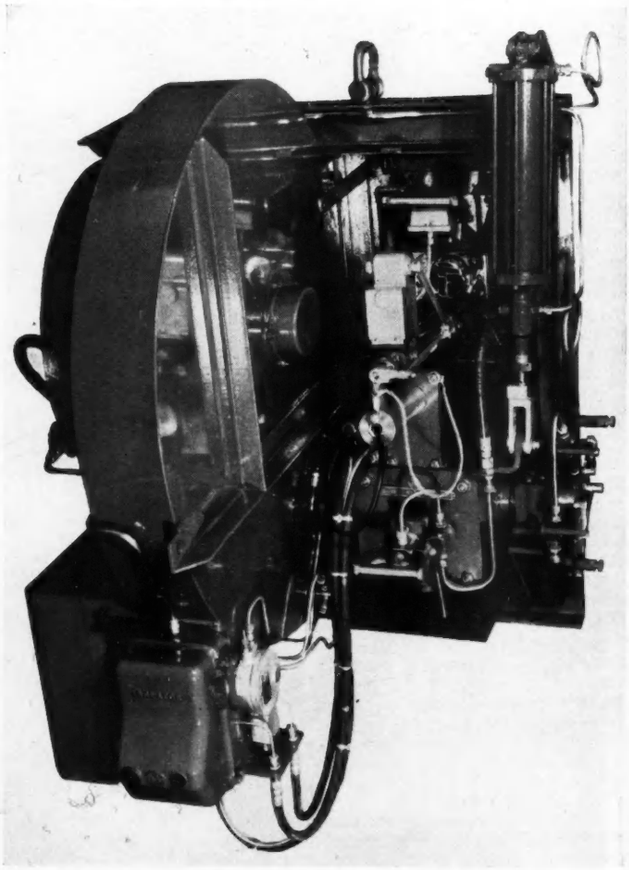
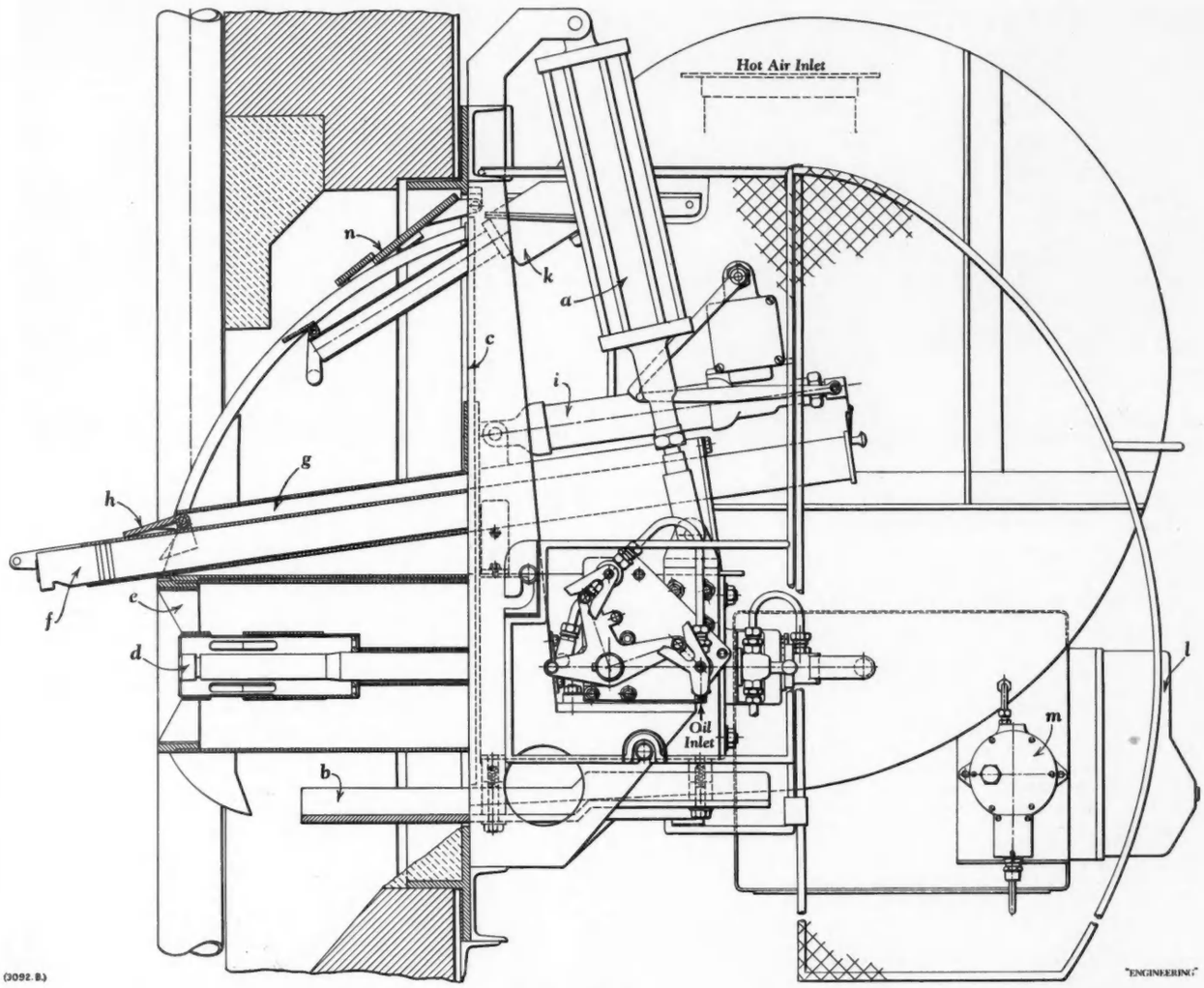


Fig. 1 Front view of the fuel-oil "initiator" in the firing position. When not in use it is retracted from the furnace.



a Main air cylinder
b Main sealing plate
c Closing plate
d Sprayer
e Swirler blades
f Low-tension ingniter
g Igniter housing
h Igniter housing door
i Igniter air cylinder
k Electronic viewer
l Fan contactor
m Air pressure switch
n Secondary sealing plate

Fig. 2 Side elevation of initiator from the oil inlet side.

draught fan and to place the appropriate initiators in operation.

Further tests by the Southern Division engineers have shown that there is a considerable saving in fuel cost when the initiators are employed alone compared with the usual combined coal and oil arrangement; and that further savings, owing to reduced maintenance of the superheater and auxiliary gear and conservation of the feed water, are also possible. Moreover, there is a saving in oil due to the rapid ignition and high intensity of the flame developed.

COMBUSTION STABILITY CONTROL

A desire for rapid operation has led to the development of a system whereby the initiators are automatically introduced into the furnace as the temperature falls. This consists of twin electronic viewers. These viewers, one of which is shown at *k* in Fig. 2, have been named the "monitor viewer" and the "lock-out viewer," and are placed side by side in the furnace wall in a position where they can scan the hottest zone. The monitor viewer is arranged so that it closes a relay at a pre-determined low furnace temperature and this causes a selected initiator to come into operation. Any failure in the circuit also causes the initiator to operate, thus providing a safeguard aginst the risk of explosion. As an additional precaution the lock-out viewer, which is on a separate circuit, is set to close a relay if a furnace is extinguished, thus cutting off the electricity supply to the initiators and rendering them inoperable.

Observations at Earley showed that during two-shift operations this control gear operated about half a minute before the pulverised fuel flame became extinguished.

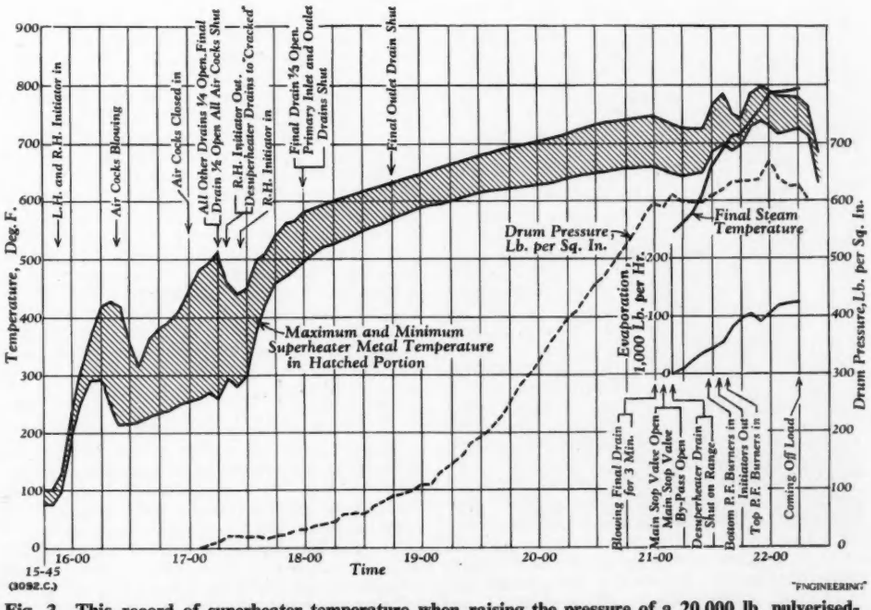


Fig. 3 This record of superheater temperature when raising the pressure of a 20,000 lb. pulverised-fuel boiler shows that that the superheater is not subjected to dangerous temperatures.

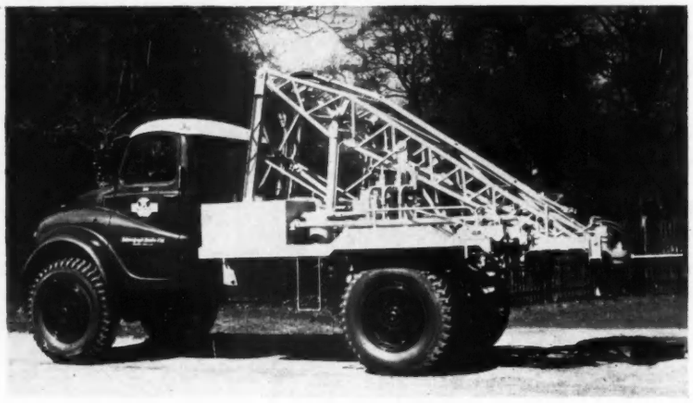


Fig. 1 " Drillmaster " power-arm drill in travelling position. The rig, which is mounted on a lorry, can be lowered for transit.

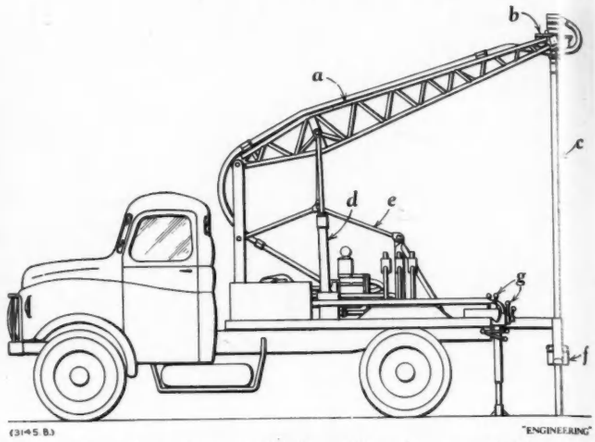


Fig. 2 General arrangement of lifting and lowering arm and linkage system. Jacks (d) raise and lower both the head (b) and the tubular arm (a).

TESTING E.H.V. TRANSFORMERS

Voltages up to 1,210 kV have been used by C. A. Parsons and Company, Limited, Heaton Works, Newcastle-upon-Tyne, for testing the first of the seven 120 MVA 3 phase 275/132 kV auto-transformers they are making for the Central Electricity Authority. Type tests on the transformers comprise three full waves at 1,050 kV and two chopped waves at 1,210 kV applied to the 275 kV bushing on two phases, and three full waves at 550 kV and two chopped waves at 635 kV applied on two phases of the 132 kV side.

The impulse generator used for the tests has a rated voltage of 2½ million in 12 steps and has an output of 60 kW seconds. The generator has good regulation characteristics and can produce a standard impulse wave form of $\frac{1}{50}$ micro-second —within specified tolerances—on very large E.H.V. transformers. In the construction for the impulse generator, all the separate stage condensers are oil immersed and are housed in two bakelised paper tanks which form the main structure of the generator embodying the trigger gaps, the inter-stage and other resistors. One electrode of the rod gap is incorporated in the generator and can be remote controlled. In addition, the generator when not in use can be lifted as a unit outside the test area in a separate steel container which also affords protection during storage.

★ ★ ★

HEAT CALCULATIONS ON SLIDE RULES

Two slide rules for heat calculations are made by Potter's Insulations, Limited, Tameside Mills, Park-road, Dukinfield. The first is to calculate the economic thickness for heat insulation of steam pipes; the variables are represented on six scales, five of them on movable slides. The variables which have to be known for any given installation are: cost of insulation in pence per sq. ft. per inch thickness; thermal conductivity of insulating material (B.Th.U. per inch per square foot per hour per deg. F. temperature difference); value of the heat to be saved in pence per useful therm; temperature of the hot surface in deg. F.; repayment time, or the time in which the cost of the insulation can be recovered by the value of the heat saved; and size of the pipe to be insulated. The result is given in inches on the seventh scale.

The heat loss calculator has 16 scales of which seven are slides, and the data required are: diameter over insulation, outside diameter of pipe, thermal conductivity of insulating material, surface coefficient, and temperature difference between the hot surface and the ambient air. The result is read off directly in B.Th.U. per hour.

A LORRY MOUNTED ROTARY POWER-ARM DRILL

TO SIMPLIFY OIL AND MINERAL PROSPECTING

The rotary power-arm drill which has been developed by Hands-England Oilfields Equipment, Limited, Letchworth, Hertfordshire, is intended to reduce the time taken and the labour required in oil and mineral prospecting and in water-well and quarry blast-hole drilling. For this purpose, as will be clear from Figs. 1 and 3, it is mounted on a lorry and weight has been saved in the design of the rig, thus facilitating both operation and maintenance. The arrangement is such that additions to the drill pipe can be quickly made with the result that the circulation of the drilling fluid is stopped for a minimum period and there is little difficulty in returning the bit to the bottom of the hole, when the ground is soft.

ARM LOWERED FOR TRANSPORTING

The general arrangement of the Drillmaster, as the equipment is called, is shown in Fig. 2. It consists of a tubular arm *a* of alloy steel which is pivotted at the front end of the vehicle and is cross-biased to ensure rigidity, as well as of a rotary head *b*, which is mounted in trunnions and turns the drill pipe *c*. Both arm and head are raised and lowered by the jacks *d*, which are mounted a short distance behind the front pivot point. A system of links *e* is attached near the front end of the arm *a*. This is a modification of the well-known Scott-Russell straight-line motion and ensures that the head travels vertically upwards and downwards over the distance permitted by the jacks. The first length of drill pipe and the bit is held by a guide *f*, which is mounted below the head *b* and a short distance above the ground. The bit is thus prevented from wandering when the drilling operation is begun. Thereafter, the guide reduces the slip in the drill string and this assists in maintaining a straight hole. For transport purposes the arm is lowered, as shown in Fig. 1, while Fig. 3 shows the equipment in its working position.

ROTARY HEAD

The rotary head consists of a thick-walled spindle through which the drilling fluid is passed to the string. Both it and the pipe are rotated at a speed of from 80 to 240 r.p.m. by two hydraulic motors, each with an output of 15½ h.p. The drive is through gearing mounted on the head, which is supported in roller bearings to take up the radial load and in a duplex hull bearing to withstand the thrust in both the upward and downward directions. Its trunnions run in double-row spherical bearings which are contained in housings welded on to the end of the arm *a*.

In addition to the drive for the rotary head, twin hydraulically cushioned jacks with a hoisting capacity of 3,990 lb. at a speed of 120 ft. per min. are provided for lifting, and there is a power feed of 3,500 lb. at 8 ft. per min. for operational purposes. There is also a 3½ in. by 5 in. duplex mud pump. The hydraulic circuit is arranged so that three forward and three reverse speeds are obtainable at the head and two up and two down speeds at the jacks. The low-speed closing of the jacks allows additional weight to be added to the drill string when required. All the hydraulic lines are protected by relief valves so that it is possible to stall the rotary head or attempt to overload the lifting capacity of the arm without causing damage to the equipment. Control is effected from the position shown at *g* in Fig. 2.

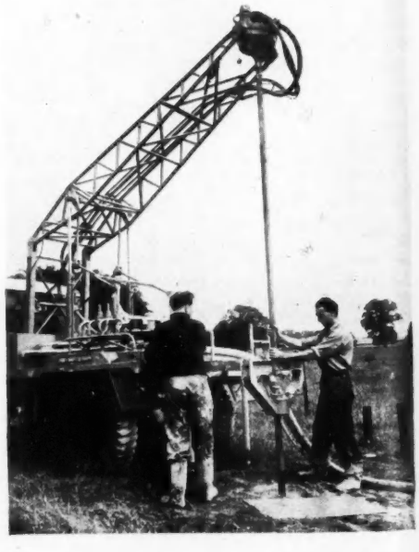


Fig. 3 The drill in working position, showing rotary head, drill pipe and guide. The rotary head consists of a thick-walled spindle through which the drilling fluid is passed to the string.

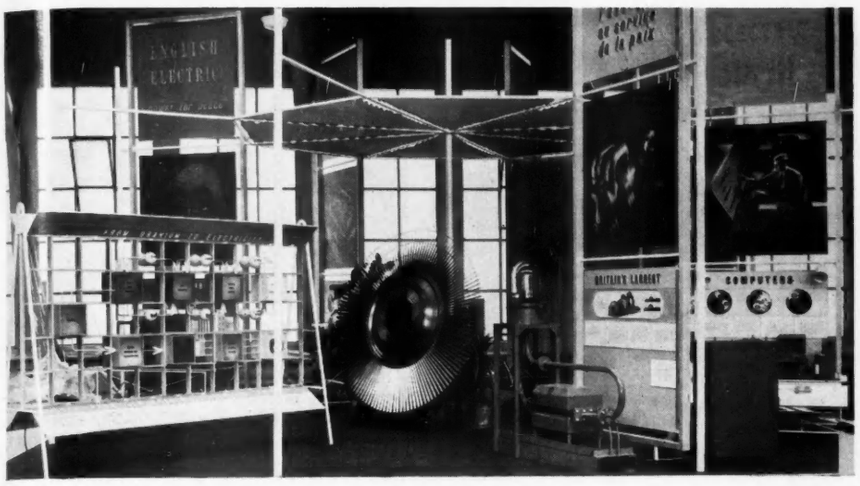


Fig. 5 In the right foreground of the English Electric Company stand can be seen a flat linear induction pump suitable for pumping liquid metals (such as liquid sodium) used as reactor coolants.

ENTERPRISE AT GENEVA

Continued from page 355

In this article we continue our account of the British industrial exhibits at the atomic energy fair in Geneva, and begin by describing the stands of two further groups of companies formed to undertake complete nuclear power projects. Following this we deal with the fabrication and application of metals, referring in particular to the exhibit of Tube Investments, Limited, and finally describe some of the instruments which were on view. These were in two main classes: those used in the study and control of nuclear processes and those which apply nuclear techniques—by means of radioactive isotopes for example—to problems in a wide range of industrial and other fields. We have already mentioned the excellent presentation of the British stands; that of the English Electric Company shown in Fig. 5 above was typical of the majority.

LINEAR INDUCTION PUMPS

The English Electric Company, Taylor Woodrow, Limited, and Babcock and Wilcox, Limited, who are associated as a group, had separate stands representing the parts being played by each in the development of atomic power. The English Electric Company, Limited, Marconi House, Strand, London, W.C.2, for example, indicated its work in the field of generating plant and associated equipment, the design of nuclear reactors and the manufacture of pumps and blowers for reactor coolant circulation.

Of particular interest was the flat linear induction pump which can be seen in the right foreground of Fig. 5. This pump, which was developed by the Nelson Research Laboratories of the English Electric Company, has been designed for pumping liquid metals and will therefore be suitable for nuclear power installations in which reactor cooling is effected by such means as liquid sodium. For demonstration purposes it was shown on the exhibit pumping liquid mercury.

Pumps in this series can withstand static pressures up to 120 lb. per square inch and temperatures up to 350 deg. C. and may be employed with metals that have become radioactive. Capacities range from 25 to 2,500 gallons per minute but for flows lower than 100 gallons per minute an annular version of the pump is used. There are no moving mechanical parts and hence no bearing or sealing problems, and the only condition for operation is that the pumped fluid be electrically conductive. Currents are induced in the liquid metal and the interaction between their associated magnetic fields and the applied field provides the force necessary for pumping. The output pressure is substantially constant throughout each cycle of supply frequency.

The English Electric exhibit also included a fully-bladed rotor disc, transmission systems, switchgear, control equipment, a model of Deuce (Digital Electronic Universal Computing Engine), and models of power stations, a mobile generating set and two locomotives. The company's work on particle accelerators was also represented.

Fig. 6 Taylor Woodrow have been responsible for building construction at Calder Hall including the cooling towers; the interior of one is shown here.

BUILDING ATOMIC POWER STATIONS

An essential item of any power station is the fabric in which the plant is housed, but owing to the special nature of atomic power production and the need for shielding, construction projects of this kind present peculiar problems of their own. Taylor Woodrow, Limited, of Ruislip-road, Southall, Middlesex, have been called upon to tackle such problems in the building of the Calder Hall atomic power station, which is now nearing completion, and their exhibit included a number of large (up to 17 ft. by 11 ft.) photographic enlargements illustrating this work. The stand also included a 16 ft. high plaster figure of a man climbing tubular steel scaffolding.

Taylor Woodrow, Limited, have been awarded the building and civil-engineering contract for the construction of a second Calder Hall atomic power station, which will be known as Calder Hall B and will be built alongside the original station. The new station will be identical with the first and will take two and a half years to complete. The work will include construction of the foundations, two 120 ft. high reactor buildings with a turbine hall and two-storey administration block between, two 300 ft. cooling towers, and ancillary works including roads, drainage, fencing and ducts.

Taylor Woodrow have also started on another atomic power contract for the United Kingdom Atomic Energy Authority; this is for the preliminary site works at Chapelcross power station, Annan, Dumfriesshire. The consulting engineers are Merz and McLellan. A view of construction work on the first Calder Hall station showing the inside of a cooling tower appears in Fig. 6.

FUSION-WELDED HEAT EXCHANGERS

The third member of the group is Babcock and Wilcox, Limited, Babcock House, Farringdon-street, London, E.C.4, and their stand illustrated the theme of atomic power development through the medium of steam; this was represented in three phases: past, present and future. It showed, for example, the part being played by Babcock and Wilcox in the construction of Calder Hall, and indicated the work being carried out on such long-term projects as "packaged" and mobile atomic power units, which may revolutionise site engineering. The focal point of the exhibit, which is illustrated in Fig. 11 and is another example of the high standard of presentation, was a facsimile of one of the eight 80 ft. steam generating towers or heat exchangers made for Calder Hall. One of these can be seen in position in Fig. 7 shortly after erection.

Each tower consists of a heavy steel shell, through which hot gas (carbon dioxide under pressure) from the reactor is continuously circulated. Inside the tower are many hundreds of feet of steel tubes, through which water flows to be converted by heat from the gases into superheated steam for driving turbo-generators. The steam plant is in three sections, one for preheating, another for evaporation and the third for superheating; in this way maximum

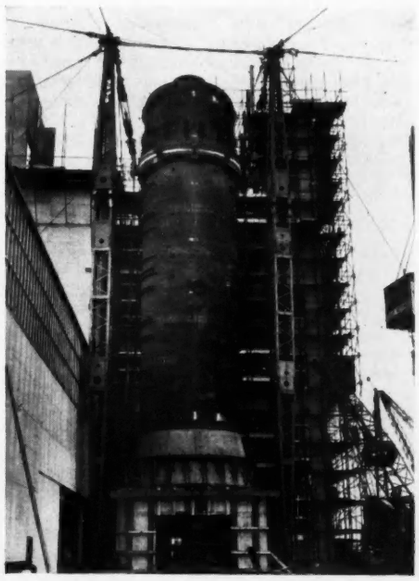


Fig. 7 A steam generating tower made by Babcock and Wilcox for Calder Hall. It has preheating, evaporating and superheating sections.

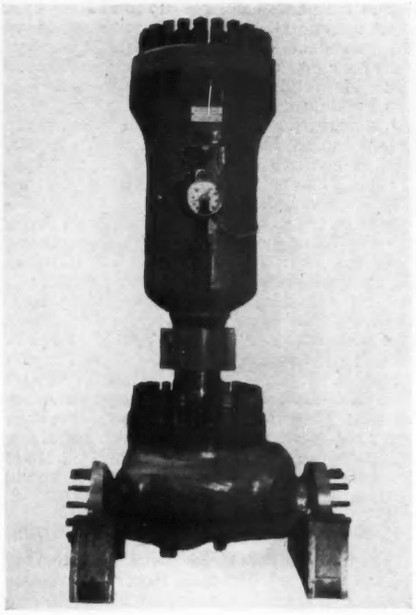


Fig. 8 A pump for atomic energy applications should run for long periods without maintenance and be subject to the minimum leakage; the Hayward Tyler glandless circulating pump fulfils these conditions.

economy can be obtained. After passing through the steam-raising towers, the cooled gas is recirculated by powerful blowers back to the reactor, where the cycle is repeated.

DOUBLE PRESSURE STEAM CYCLE

One of the most interesting features of the installation is the use of a double-pressure steam cycle in order to achieve the highest possible efficiency with the low temperature (compared with a conventional furnace) at which the gas enters the steam towers. Each tower contains in effect two sets of steam-raising equipment with separate high-pressure and low-pressure economiser, evaporator and superheater sections, each having its own drum and feed pump. The turbine plant will of course be designed with a low-pressure section which will receive live steam directly, in addition to steam which has been expanded in the high-pressure blading.

In order to obtain the maximum heat transfer within the towers all heating surfaces are of stud-tube construction to give extended surface area. The studs are flash-welded and have smooth surfaces and a profile giving good aerodynamic properties. An important requirement of the internal heating surfaces is that there should be no leakage of steam or water into the coolant gas, otherwise contamination of the reactor interior—the fuel elements and the graphite—would result. The design therefore involves no joints inside the pressure shells except those which, once completed in the shops and exhaustively tested, will not need to be broken throughout the anticipated life of the plant. What is more, the high pressure of the coolant gas (due to the need for economy in blower power) necessitates that the whole system be built to withstand this pressure without any possibility of leakage. The carrying out of this project has therefore demanded wide experience in the production of fusion-welded pressure vessels.

STEAM TURBINES AND REACTOR SHELL

Another group with members who have separately made contributions to the building of Calder Hall is the Nuclear Power Plant Company, Limited, which has its registered office at Heaton Works, Newcastle-upon-Tyne, 6, and its design headquarters at Booths Hall, Knutsford, Cheshire. This group, whose stand was primarily devoted to an announcement of its formation, membership and purpose, includes C. A. Parsons and Company, Limited; A. Reyrolle and Company, Limited; Whessoe Limited; Strachan and Henshaw, Limited; Alex. Findlay and Company, Limited; Clarke, Chapman and Company, Limited; Head, Wrightson and Co., Ltd., and Sir Robert McAlpine and Sons Limited. The first five of these companies have taken part in the Calder Hall project, while Sir Robert McAlpine and Sons have long experience in power-station construction and Clarke, Chapman and Company in steam-raising and allied equipment.

Head, Wrightson and Company have worked extensively on heat-exchange plant, and have also been engaged for some time in the design and building of various kinds of reactor at home and abroad; they have also designed, and are in the course of erecting, a large heavy-water plant in New Zealand. The group as a whole has been formed to design and construct atomic power stations in any part of the world.

The work that has already been carried out separately by members of the group at Calder Hall includes the provision of pressure vessels or outer shells for the reactors by Whessoe Limited, and the manufacture of the circulating gas blowers and pipework by C. A. Parsons and Company, who are also supplying the turbo-generator plant.

In addition, orders have recently been placed with C. A. Parsons for plant to be installed in the second section of the Calder Hall station; this will be similar in all respects to the first section. Plant for a second atomic power station at Chapel Cross in Dumfriesshire has also been ordered. This will comprise a further eight turbo-generators, each with an output exceeding 20 MW making a total with the two sections at Calder Hall of 16 turbo-alternators, 32 gas circulators, eight dump condensers together with all the associated gas duct work for the eight reactors.

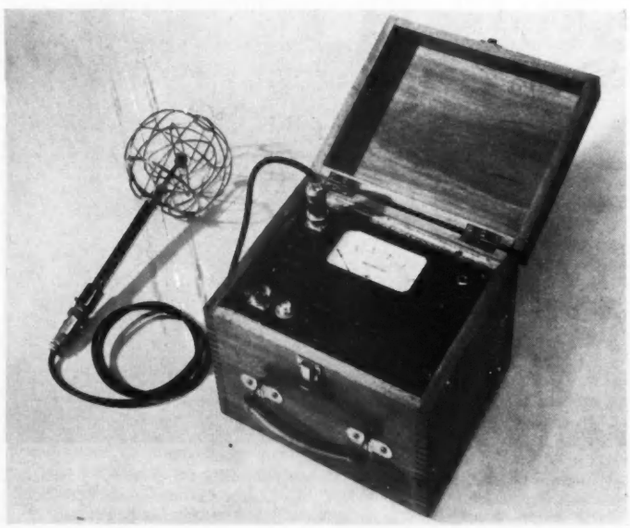


Fig. 9 The ionisation anemometer type 750 made by Isotope Developments Limited is designed for the measurement of very low speed air currents in the range 10 to 300 feet per minute.

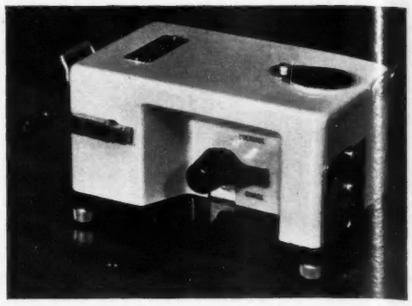


Fig. 10 The Ericsson dosimeter charging unit employs a hand generator and metal rectifier; it thus requires no external power supply. The fibre can be viewed without removing the instrument from the charging unit.

TUBES, WELDS AND SPECIAL METALS

The study and fabrication of metals is a particularly important part of reactor and atomic power station technology, for not only are the fuel elements made from unusual metals with special properties, but there are numerous other metallurgical problems associated with an atomic energy installation. Some of these arise from the high pressures and temperatures involved, the use of corrosive fluids and liquid metals, the jointing of expensive to more work-a-day materials, and the damage due to irradiation. Tube Investments Limited, the Adelphi, London, W.C.2, have carried out a wide variety of research in this field and their exhibit at the Geneva fair indicated how successful they have been in their investigations.

Apart from tubular and other components, mainly in stainless steel and aluminium, already developed to meet the generally increasing temperatures and pressures and corrosive conditions of contemporary industrial processes, but suitable also for atomic energy applications, Tube Investments exhibited items in various special materials. These included tubes in uranium, niobium, vanadium, tantalum, beryllium, thorium and zirconium. Some of these metals were not produced in sufficient quantities to attempt working until the past three or four years, but special techniques have now been developed for their fabrication.

Also shown were a 5 ton seamless stainless-steel dissolver shell, 17 ft. long and of 30 in. bore, for processing uranium; a zirconium tube with a wall thickness of three thousandths of an inch and a zirconium coil; a uranium bar bonded with an outer sheath of zirconium; bi-metal tubes; tubes lined with graphite, glass and plastics and a series of couplings for joining such tubes of different metals; and a range of irradiated plastics materials. It is also worth noting that Tube Investments are the makers of what is believed to be Britain's first rolling mill designed specifically for uranium work.

Of particular interest was an example of a method for linking two dissimilar alloys, known as the "Chesterfield-Unisteel" joint. The need to join expensive metals with special properties to more commonplace alloys is of appreciable importance in the atomic power industry and a T.I. company has developed a technique for coupling ferritic and austenitic steels in such a way that the joint can withstand operating conditions in modern high-temperature boilers. Owing to a marked difference in the expansion properties of these alloys, great difficulty has

been experienced in joining austenitic steels—necessary at the high temperatures in superheaters—to the ferritic steels which are economically desirable in the lower-temperature zones. Joints of this kind have been achieved by an extrusion process and one of these couplings, together with a section of the extruded joint showing the actual weld, was on view. The joint resembled a long oblique splice, and in this way forces due to differential expansion could be distributed over a large area.

ENHANCING THE PROPERTIES OF PLASTICS

The work of T.I. in the plastics field covers the exposure of long-chain polymer compounds to atomic radiation, by which means they become cross-linked and their properties enhanced. The process is similar to the vulcanisation of rubber, but takes place without the addition of chemical vulcanising agents and without heat treatment. Moreover cross-linking by radiation can be produced in materials for which no alternative chemical process is available.

The effect of cross-linking is to convert long-chain polymers to a non-melting structure which is insoluble in the usual solvents. In the case of polythene, for example, radiation converts the material from one which melts and flows at about 115 deg. C. to one which acquires rubber-like properties at this temperature. By radiation, silicone fluids containing carbon or fine silica powder, which act as reinforcing agents, can be converted to rubber-like materials and the tensile properties improved.

GLANDLESS CIRCULATING PUMP

The problems associated with the steam, liquid-metal or hot-gas circuits in atomic power stations are not restricted to metallurgy and metal fabrication alone; there are also mechanical problems of process control arising from the peculiar operating conditions involved. It follows that nuclear technology also requires a special approach to the design and construction of such items as instruments, valves and pumps, and a pump suitable for use in these circumstances was shown on the stand of Hayward Tyler and Company, Limited, Luton, Bedfordshire. Eighteen pumps of this kind, one of which is illustrated in Fig. 8, are being supplied to Babcock and Wilcox, Limited, for the atomic power station at Calder Hall.

Fig. 12 The Baird and Tatlock "Analmatic" automatic "laboratory" can perform complete analyses—from sample to recorded results—without human agency. The version shown is for the analysis of uranium liquors.

Fig. 11 Typical of the excellent presentation of many British stands was that of Babcock and Wilcox Limited. The exhibit represented the theme of atomic power development through the medium of steam in three phases: past, present and future. Mobile and packaged atomic power plants for the exploitation of remote sites were one of the future possibilities envisaged.

Perhaps the most desirable features of a pump employed for atomic energy applications are that it should be capable of long periods of maintenance-free running, and that leakage of the pumped liquid should be a minimum. It is with these qualities in view that the Hayward Tyler pump has been designed. It is built to withstand pressures of several thousand lb. per square inch and for horse-powers up to 2,000. For boiler circulation duties the pump and motor case are made of carbon or alloy steel, but for duties where contamination of the water must be kept as low as possible—for example in circulation through a reactor—the entire unit is made of corrosion-resistant material. The company is also co-operating with the Atomic Energy Research Establishment in the design and production of a similar unit for pumping liquid sodium.

AUTOMATIC LABORATORY

Although Baird and Tatlock (London) Limited, Chadwell Heath, Essex, were not exhibiting in the Palais des Expositions, a version of their "Analmatic" automatic "laboratory" was on the official United Kingdom stand in the Palais des Nations; this unit, which is illustrated in Fig. 12, has been designed specifically for the analysis of uranium liquors and has been developed in co-operation with the Atomic Energy Research Establishment. For uses of this kind, automatic equipment is specially valuable since the problems of radiation hazards and screened manipulation do not arise.

In general, chemical analysis is carried out by adding reagents to a test sample and then determining certain characteristics by means of burette readings, *p*H measurements, colorimetric checks and changes in temperature. Appropriate calculations then give the answer required. In an Analmatic laboratory these operations are performed entirely automatically—from taking the sample to recording the final result. What is more, the Analmatic laboratory can be connected to a full-scale production process so that any variations in the main plant from a predetermined standard may be detected and suitable corrections made; the necessary adjustments to control valves and mechanisms would be carried out completely automatically by means of signals from the Analmatic set.

A set normally comprises one or more standard units developed for specific laboratory techniques; these units are assembled together with their power supplies and services in standardised cabinets and interconnected in such a manner that the desired process is carried through and the result recorded without human intervention. The central operations are effected by metering and mixing units; various electro-magnetically controlled valves admit the reagents and solutions to the vessel and electrical probes determine their volumes. Mixing is achieved by gas stirring.

In the Analmatic laboratory used for the analysis of uranium liquors, measured volumes of samples are drawn automatically from four different sources in turn. To each of these samples two reagents are added and the mixture is then forced up the centre of a double-walled tube by gas pressure and mixed in a chamber at the top of the tube. Subsequently the mixture is delivered to an absorptiometer, where the intensity of the colour produced by the reaction is compared with a known standard, so that the concentration of the sample can be determined. In another version a *p*H measurement can also be made. Finally, the results are collected by a recorder unit.

The order of operations and their timing is governed by a sequence control and time pulse unit. In addition this unit must check that the previous operation has been completed satisfactorily before its successor is allowed to proceed. This is effected by means of feed-back signals from the different mechanisms of the laboratory. The sequence control unit is also linked to an illuminated diagram giving visual indication of the state at any time during the process. A fault alarm rings whenever the sequence of operations is interrupted by, for example, an inadequately completed stage, and the action stops until the fault is cleared. A fault-finding multi-point switch connects each main electrical circuit to a pilot light in turn, thus enabling the fault to be rapidly located.

Although the units themselves are standard, the Analmatic laboratories can be assembled to suit the requirements of any particular process, and in some cases several processes can be performed with one set; but to function economically a set should be used more or less continuously for predetermined analyses. In general, the Analmatic laboratories can handle both liquids and gases, and additional units are at present being developed to extend their range of laboratory techniques; the handling of solids, centrifuging, filtering and combustion are some of the problems being tackled.

INSTRUMENTS AND ISOTOPES

Isotope Developments, Limited, Finsbury Pavement House, 120 Moorgate, London, E.C.2, exhibited a wide range of laboratory and industrial equipment employing nuclear techniques, and a variety of instruments for use in conjunction with experimental and power reactors.

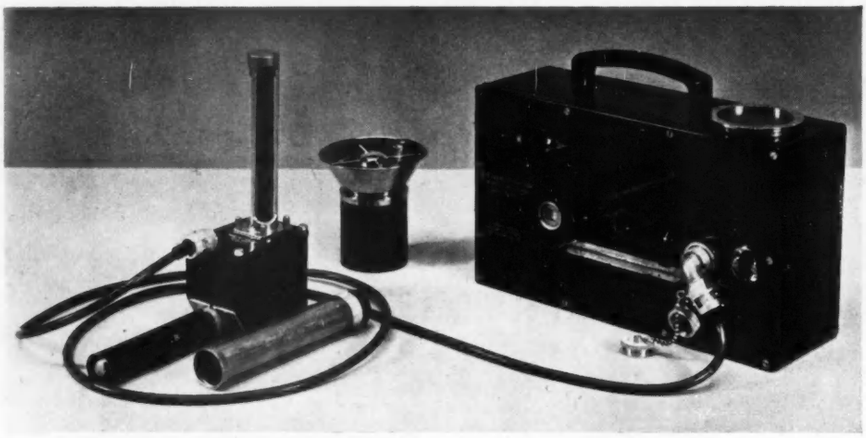


Fig. 13 The Ericsson field ratemeter (type 1368) can be used for such purposes as tracing radioactive veins in rock or assaying radioactive ore in the field.

Among the laboratory equipment were instruments capable of performing any precise count or rate measurements in connection with ion chambers and scintillation, proportional and Geiger counters, and embracing beta- and gamma-ray spectrometry, general research and diagnostic and therapeutic procedures in hospitals employing radioactive isotopes. I.D.L. products in this field include their prescaler, type 501—a fast scaling unit for high-speed scintillation counting; a scintillation counter head (type 653) with interchangeable caps for beta and gamma measurements; an automatic scanning unit (type 674) for use in conjunction with the same company's single-channel pulse analyser (type 672); a precision ratemeter (type 550) which with the probe provided may be used as a self-contained contamination monitor; a portable survey meter (type 580) operated by battery and suitable for measuring dose-rates of beta, gamma and X-rays; and ranges of scintillators (including high-resolution sodium iodide capsules and a fast plastic phosphor) and Geiger-Müller tubes applicable to the counting of solid, liquid and gaseous samples.

Many methods of checking processes and controlling production in industry embody isotopes and nuclear techniques. Examples of such equipment are the I.D.L. beta gauge which is designed for the accurate non-contact measurement of weight, thickness or density of paper, plastics, rubber, metal foils and other sheet materials; and the company's package monitor (type 210) which is used to check the filling of proprietary products in liquid, paste or solid form into paperboard cartons, metal cans or collapsible tubes. Similar in principle to the beta gauge is a gamma gauge suitable for the high-speed thickness measurement of hot and cold rolled sheet steels and other metals.

Fig. 9 shows the I.D.L. ionisation anemometer (type 750), which is an instrument for investigating very low-speed air currents in the range 10 to 300 ft. per minute. Other items are the static eliminator, type 405, for eliminating static electricity charges on sheet materials, during such operations as folding guillotining or wrapping, or in spreading plants where inflammable vapours are involved; and the type 875 wall-thickness gauge. This instrument has been recently introduced and is a reflection gauge for determining the thickness of flat or curved surfaces on sheet materials and pipes. It is particularly suitable for use in the field and requires no contact fluid or preparation of the metal surface.

A prototype geological survey instrument has also been introduced; it is designed for close ground prospecting for radioactive materials and embodies a scintillation counter.

Isotope Developments Limited are also concerned with control, safety, health and experimental equipment for use on reactors and adjacent to them.

DOSIMETERS AND RATEMETERS

Instruments for the detection and measurement of radioactivity were among the most important features of the Ericsson (Beeston, Nottingham) stand and included dosimeter, monitoring and ratemeter equipment. Also shown were examples of the company's cold-cathode tubes, among which were a new 100 kc. per second dekatron counter tube (type GC 10Q); and the first of a range of high-voltage low-current stabilisers for regulating supplies to Geiger-Müller tubes and scintillation counters (type GD 340W).

The Ericsson exhibits were arranged in a manner that made them especially interesting to the visitor. For example, to demonstrate the radiation monitor type 1320 a source of gamma rays was hidden in a model wall to represent radioactive contamination in a laboratory or other room; visitors were invited to use the monitor to locate the source. Another demonstration involved a scaling unit (type 1221), and illustrated the method of making an assay of a radioactive ore sample in the laboratory.

The company also displayed their field ratemeter (type 1368), which is shown in Fig. 13, and is an improved transistorised version of an earlier model, the type 1292. The new unit includes an extra low-intensity Geiger-Müller tube for use where the background count is high. In the exhibit it was represented in two applications: first tracing the course of radioactive veins in a rock face and secondly assaying radioactive ore in the field; in each case the beta probe would be required.

An instrument with a wide range of applications in industry and nuclear technology is the vibrating-reed electrometer (type 1086). It can measure currents of the order of 10^{-16} amperes and its input impedance is approximately 10^{14} ohms. It comprises two units connected by a cable; these are a direct-current/alternating-current converter and head amplifier, and an indicator unit (made by Electronic Instruments, Limited).

Fig. 10 shows a dosimeter charging unit which was also exhibited. This portable instrument employs a hand generator and metal rectifier, and therefore requires no external power supplies. The dosimeter fibre may be viewed without removing the instrument from the charging unit.

INDUSTRIAL RADIOGRAPHY

The use of radioactive sources for examining welds, sheet metals, castings and other components in a variety of materials by radiography techniques has become an established practice in industry, and equipment designed for this purpose to permit the safe handling of radioactive isotopes has been developed. Teleflex Pantatron, Limited, Chadwell Heath, Essex, who were exhibiting at Geneva, specialise in such equipment. Their products include the "Pantatron Minor" (TR.1000), which is a portable unit suitable for use with sources having gamma-ray energies from 0 to 150 keV, and in particular thulium 170 sources; the "Pantatron I," (IR.0000A and IR.0000B), which is designed for use with iridium 192 or an equivalent source having gamma-ray mean energies in the range 0 to 660 keV; the "Pantatron II" (CR.500, CR.1000 and CR.2000) for sources up to 3 MeV (cobalt 60, radium, radon, etc.); and the "Panatron III." Units for the safe transit or storage of radioactive isotopes are also made.

The Pantatron III, which is shown in operation in Fig. 14, has been designed for industrial radiography of metals and other materials; the range of use with steel covers thicknesses from 2 in. to 8 in., with sources having gamma-ray energies up to 3 MeV; cobalt 60, for example, is a suitable source. There are two versions, the CR.5000, which can take up to 5,000 millicuries of cobalt 60, and the CR.10000, which takes up to 10,000 millicuries. Pantatron III group containers are made to hold four isotopes. For single exposures and selection of isotopes it is only necessary to turn a handle.

Fittings are provided for the attachment of remote controls which enable the isotope to be located at any required position; for example, for panoramic exposures in which a large number of items disposed round the unit are inspected simultaneously or for application inside pressure vessels, under water or any other place normally difficult of access. Pantatron mechanical controls enable the isotope to be sent out along guide tubes to the desired position, while the operator stands at a safe distance.

TABLE.—SOURCES RECOMMENDED FOR INDUSTRIAL RADIOGRAPHY

Isotope of	Cobalt 60 (Co 60)	Caesium 137 (Cs 137)	Iridium 192 (Ir 192)	Thulium 170 (Tm 170)
Half life of source	5·3 years	33 years	70 days	127 days
Type of gamma rays emitted in 1,000 electron volts (KeV)	1·171 1·331	660	610, 600 580 etc.	84
Roentgen output at 1 meter in milliroentgens; per hr. per mC	1·35	0·32	0·27	0·006
Lead shielding to reduce the radiation to one tenth of its strength	2 in. (51 mm.)	15/16 in. (23·9 mm.)	0·42 in. (10·7 mm.)	0·05 in. (1·5 mm.)
Recommended for radiography of:	Steel or equivalent ½ in. to 12 in.	Steel ½ in. to 3 in.	Steel ½ in. to 2½ in.	Light alloys, plastics and rubber assemblies. Steel up to ½ in.
Size of sources standardised..	2 × 2 mm. (200 mC) 4 × 4 „ 1,500 „ 6 × 6 „ 3 C and over	2 × 2 mm. 250 mC	2 × 2 mm. (700 mC) 4 × 4 „ 3 C 6 × 6 „ 6 C and over	2 × 2 300 mC
Approx. price for source only..	From £3 to £50	£20 to £150 according to the strength	£3 to £20 of the source supplied	£3 to £12
One Curie of source is useful in	10 years	66 years	5 months, but a 5C source is useful in 1 yr.	8 months
Surface shielding required for 1 Curie	6 in. of lead	5 in. of lead	2½ in. of lead	1 in. of lead

Fig. 14 The Teleflex Pantatron III, which can be controlled remotely, permits the safe use of radioactive isotopes for industrial radiography.

The standard remote-control apparatus consists of a control panel which houses the operating unit, up to 40 ft. of cable, and a meter to measure the length of travel of the isotope. Between the control panel and the container is a section of covered cable the length of which is determined by the strength and type of isotope. The cable is attached to the isotope holder and passes through the container when the source is pushed along the tubes. The apparatus also includes guide tubes, terminal tubes and adaptors.

The Pantatron III itself consists of shielding in a dense metal encased in a strongly-built shell; the operating mechanism and trunnion base permit tilting of the container through 90 deg. Among various ancillary fittings are crane hooks, castors, lock and key to prevent unauthorised use and two warning lights; one comes into action as soon as the container is unlocked and the other when the sources are moved from the position of maximum safety in the container.

The accompanying table gives data for sources recommended for industrial radiography and supplied by the Radiochemical Centre, Amersham, Bucks, of the United Kingdom Atomic Energy Authority.

As the load of the bricks comes on to the forks of the Bickerstaffe attachment, pads extend from the sides of the forks and grip the rows of header bricks so that the whole stack is lifted at once.

LIFTING OF BRICKS AND BLOCKS ON FORK TRUCKS

Attachment Dispenses with Pallets or Stillages

An attachment for standard fork trucks that is designed particularly for handling unit loads of bricks or blocks and does not involve the use of pallets or stillages, is the Bickerstaffe brick and block fork now being made in this country by R. H. Corbett and Company, Limited, Burgess Hill, Sussex. It is designed to fit any of the range of fork trucks produced by Conveyancer Fork Trucks, Limited, Liverpool-road, Warrington. In the illustration below it is shown attached to a model T.C.6 Diesel/petrol truck.

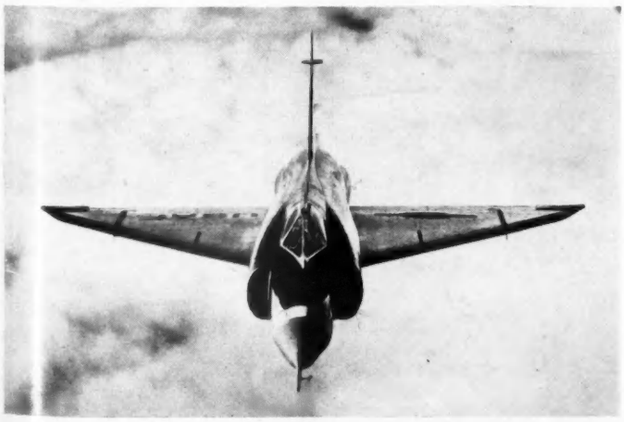
As may be seen in the illustration, the load of bricks is built up on four rows of header bricks between which the forks of the attachment will slide. When the forks have been slid fully home under the load, the lift can begin. As soon as the load of the bricks comes on the upper surface of the forks, the latter move downward slightly against a series of springs and, in moving, operate a linkage mechanism behind the backguard. Operation of this linkage causes a series of spring-loaded gripper pads mounted along both sides of each arm to be extended and to grip the header bricks between them. In this way, the complete load is lifted at once, including the header bricks which, by remaining in place, will allow the withdrawal of the forks when the load is being stacked. As the forks are lowered and relieved of the load, the main springs come into play again and the grippers retract as soon as the main load is again carried by the header bricks.

Advantages of this system include the ability to move bricks directly into or out of the kiln without any restacking. Similarly, they can be stacked for maturing without having a large number of pallets "locked-up" and probably deteriorating rapidly. Sizes of the attachment are made for all standard Conveyancer trucks, that shown being capable of handling loads up to 4,000 lb. For ease of manoeuvring, it is recommended that a shift mechanism should be employed—the standard one allows a movement of 3 in. each way which is ample for allowing the forks to be set accurately to pass between the headers.

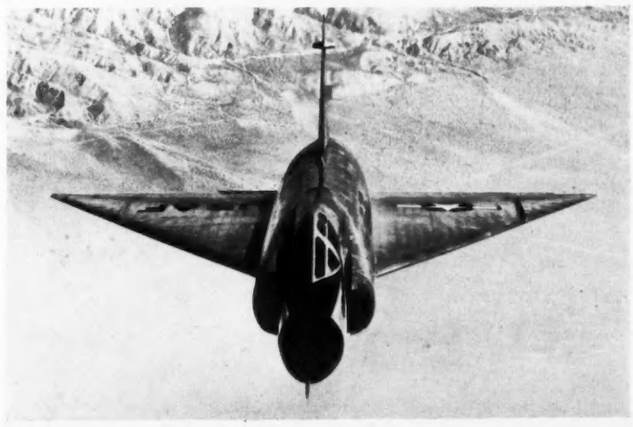
WASP WAISTS FOR LOWER DRAG

Investigations at the American National Advisory Committee for Aeronautics have shown that in a supersonic aircraft the transonic drag rise is largely a function of the combined cross-sectional area of the wing and fuselage. By reducing the fuselage cross-section at the junction with the wings so that the total area is the same as it would be for the streamlined fuselage alone, minimum drag is obtained in the transonic range resulting in greatly enhanced performance.

The new principle, it has now been revealed, has been embodied in the production version of the F.102A all-weather interceptor. This aircraft, supersonic in level flight, is designed and constructed by the Convair Division of the General Dynamics Corporation, San Diego, California, and deliveries to the United States Air Force have already commenced. The accompanying illustrations show, right, the prototype YF.102, which has a straight-sided fuselage; and, left, the wasp-waisted production F.102A. The illustration also shows the up-swept wing tips of the production machine. The F.102A is powered by a Pratt and Whitney J.57 turbojet with after-burner. The span is 38 ft., the length 68 ft., and the height 18 ft.



The production Convair F.102A supersonic all-weather interceptor has a wasted fuselage which greatly reduces the drag in the transonic range.



The prototype YF.102, which has a straight fuselage, is shown for comparison with the production F.102A on the left.

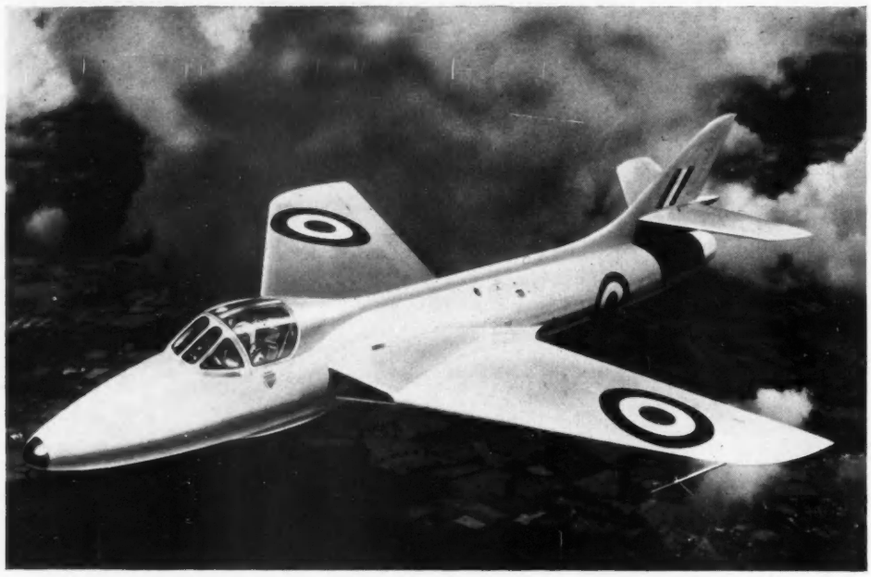


Fig. 12 Hunter two-seat tactical aircraft. Hawker Aircraft Limited.

THE AIRCRAFT INDUSTRY DISPLAY

(3) MILITARY AND RESEARCH AIRCRAFT

A welcome innovation at this year's Farnborough show was the fly-past of Vickers-Armstrongs Valiant bombers and Hawker Hunters of the Royal Air Force, and an aerobatic display by four Hunter aircraft of No. 54 squadron, R.A.F., Odiham. In this third report on the show we give some brief comments on the military aircraft that were displayed.

HUNTERS

The re-equipping of R.A.F. fighter squadrons with Avon-powered Hunter 1 and Sapphire-powered Hunter 2 aircraft is now well under way, and it was announced recently that the United Kingdom and United States governments had concluded arrangements whereby the North American F.86E Sabre aircraft in service with the Royal Air Force would shortly be exchanged for Hunters to be delivered from an off-shore procurement contract placed by the U.S. government in the United Kingdom. This exchange involves some hundreds of aircraft in service both in the 2nd Tactical Air Force and in Fighter Command.

Prototype Hunters exhibited by Hawker Aircraft Limited, Canbury Park-road, Kingston-on-Thames, in the flying display comprised the long-range ground-attack Mark 4 Hunter, powered by a Rolls-Royce Avon turbojet, which flew with underwing stores—rockets or bombs and external fuel tanks; a Mark 6 Hunter with a more powerful Avon engine, but unchanged in external shape (the dimensions are: span, 33·67 ft.; length, 45·9 ft.; and height, 13·14 ft.); and a two-seat version illustrated in Fig. 12 which, the manufacturers state, is intended to open up opportunities for wider tactical roles. Radar equipment can be installed in the nose.

P.1 SUPERSONIC INTERCEPTOR

From the technical observers' viewpoint probably the two most interesting military aircraft in the display were the two new types of fighter aircraft flown in public for the first time—the Folland Gnat light-weight tactical aircraft, and the supersonic English Electric P.1 prototype, the latter appearing on the first two days only.

Largely owing to an unwise decision towards the end of the second World War not to pursue full-scale experiments on supersonic flight, but to rely on rocket-powered model tests, Great Britain has lagged behind the United States in this field: American air-force squadrons are already equipping with level-speed supersonic interceptors and it is generally believed that the Russian air force is in no way inferior in its equipment to the United States. How far these ultra-high-speed machines are effective in combat is, fortunately, still open to proof. To date, Great Britain has on order a total of 20 pre-production supersonic interceptors of the P.1 type.

The first British machine to exceed Mach 1 in level flight, the P.1 interceptor is designed and constructed by the English Electric Company, Limited, Warton Aerodrome, near Preston, Lancashire. It has made over 100 flights since its maiden flight in August last year. The P.1 is supersonic without the use of afterburning or any other form of power-boosting. Very little information has been released on this aircraft, which is powered by two Armstrong Siddeley Sapphire turbojets, installed one above the other in the tall fuselage, with a common intake in the nose. It has been revealed that the Short and Harland SB5 variable-sweepback aircraft was used as a research model for the P.1. The planform, which Fig. 13 effectively conceals, can best be visualised as a delta form with a centraly disposed delta-shaped segment bitten out of the trailing edge.

Fig. 13 P.1 supersonic interceptor. English Electric Company, Limited.

GNAT LIGHTWEIGHT FIGHTER

The Gnat lightweight fighter aeroplane was conceived to provide a simpler, less costly aircraft than the types now in service; one which can operate with a useful military load, and in adequate numbers, from forward bases, and which offers a more realistic prospect for maintaining and replacing the machines in time of war than can be foreseen with to-day's complex aeroplanes.

Last year the Gnat's fore-runner, the Midge, designed and constructed by Folland Aircraft, Limited, Hamble, Hampshire, was the principal attraction of the flying display. The Midge, it may be recalled, is powered by a 1,640 lb. thrust Armstrong Siddeley Viper turbojet, and was constructed to expedite the aerodynamic evaluation of the Gnat pending the availability of its designed power plant, the Bristol Orpheus turbojet, an engine in the 3,000-5,000 lb. class. The prototype illustrated in Fig. 14 has a 4,000 lb. thrust engine.

Some few weeks before the opening of the Farnborough display, the prototype Gnat—which first flew on July 18—had to make an emergency landing as a result of the canopy becoming accidentally detached in flight, and the pilot had to land wheels up. Happily the damage was slight, and was repaired in time to enable the Gnat to demonstrate its excellence of handling. In appearance the Gnat closely resembles the Midge in that it has a swept-back high-midwing layout, low-set tailplane and twin fuselage intakes for the Orpheus turbojet, which is installed aft of the pilot. The entire rear fuselage can be detached for engine changes, and servicing panels on the underside give access to the engine accessories.

No performance figures may be quoted for the Gnat, but it is known to be a high sub-sonic aeroplane (later versions will be supersonic in level flight) and is expected to have a service ceiling greater than 50,000 ft., and a flight duration of more than one hour at operating height on its permanent internal fuel tanks. It has a span of 22 ft. 2 in., a length of 29 ft. 9 in., and a height of 8 ft. 10 in. The maximum fuselage depth is 3 ft. 4 in., and the track of the undercarriage—which folds backwards into the fuselage—is 5 ft. 1 in. The wing has an aspect ratio of 3·6 and a sweepback of 40 deg.

An unusual feature of the Gnat is the inboard location of the large-area ailerons which, the manufacturers claim, give the Gnat an unusually high rate of roll, said to be at least 200 deg. a second, over a wide range of speed and altitude without imposing undue twisting moment on the wings. Another unconventional arrangement concerns the air brakes, which are in fact the metal fairings of the undercarriage legs; thus, by partially lowering the undercarriage the air brakes are brought into operation, and one extra system is eliminated from the aircraft. When the undercarriage is fully lowered, a linkage

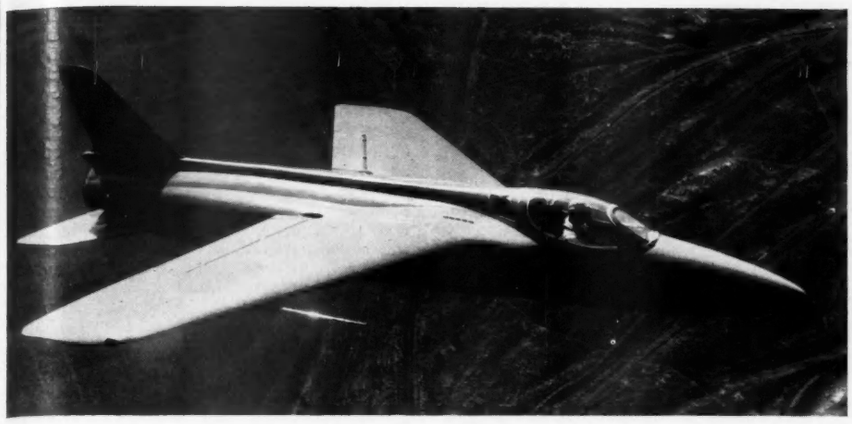


Fig. 14 Gnat lightweight fighter. Folland Aircraft, Limited.

between aileron and undercarriage converts the ailerons to landing flaps, and a demonstration of this mechanism was on view on the Folland stand in the static exhibition.

The Gnat tailplane is of the variable incidence type, as is becoming general practice for aircraft operating in the transonic and supersonic regions. In the Gnat, operation of the control column moves the elevator, which acts as a servo and is linked to a hydraulic booster unit which in turn moves the tailplane.

The small wing of the Gnat is built in one piece, and fits into a recess on the top of the fuselage where it is secured by four main bolts. No guns, fuel tanks, or undercarriage units are housed in the wing, the structural design of which can, therefore, be kept simple.

The armament comprises two 30 mm. cannon, one on each side of the fuselage. In addition, the Gnat is capable of carrying externally two 500 lb. bombs or twelve 3 in. air-to-ground rockets. Standard operational equipment includes V.H.F. radio and standby set, a distance measuring equipment, gyroscopic gunsight and radar ranging, pressurised cockpit and supplementary oxygen supply, brake parachute and a lightweight fully-automatic ejector seat.

The small dimensions of the Gnat render it readily convertible to carrier operation, since it can be accommodated on the carrier lifts without the necessity for folding wings; and the Folland company suggest that carrier hangars which can accommodate five conventional present-day naval fighters could house 14 Sea Gnats. In the static exhibition, Folland showed a model of their projected Sea Gnat, with arrester hook attached, and a mock-up undercarriage leg specially designed for a naval version by Electro Hydraulics Limited, Warrington. This unit provides for a higher rate of descent and for an alternative wheel-door arrangement to give clearance when passing over the arrester wires. Two features of the normal Gnat undercarriage which have been retained are the partial lowering to provide air brakes, and the compression of the gear during retraction to save stowage space.

FD2 SUPERSONIC DELTA

Believed to be the potentially-fastest aircraft taking part in the display, the FD2 delta-wing research aircraft was shown by its constructors, the Fairey Aviation Company, Limited, Hayes, Middlesex, for the first time. This aircraft, powered by a Rolls-Royce Avon turbojet, is designed purely for supersonic research at high altitude and, when afterburning is brought into action (it was not used during the display), the aircraft is said to surpass Mach 1 in level flight by a handsome margin.

It will be seen from Fig. 15 that the elongated nose has actually a slightly concave curvature; to minimise drag, the cockpit is very small, and in order to give the pilot an adequate view for landing, the entire cockpit forward of the aft pressure bulkhead is arranged to hinge downwards as shown in Fig. 16. " Petal "-type dive brakes are provided which are said to give an extremely rapid deceleration with no trim change.

Although the delta wing is thin, it houses the main wheels of the tricycle undercarriage when retracted. Outboard of the wing roots there are boundary-layer fences. All the control surfaces are operated through Fairey hydraulic power boosters. Air intakes for the Avon engine are situated on each side of the fuselage at the wing roots. As in most high-speed aircraft, a tail parachute is provided.

AVRO CF100 ALL-WEATHER INTERCEPTOR

Another fighter seen for the first time at Farnborough—although by no means a prototype—was the CF100 Mark 4 twin-jet two-seat all-weather fighter aircraft constructed by Avro Aircraft, Limited, Malton, Ontario (Fig. 17). It is now in service in large numbers with the Royal Canadian Air Force, to whose rigorous specification it was designed. It is, in fact, the first aircraft to be designed in Canada, and to be powered by Canadian-designed engines—7,000 lb. thrust Orenda II turbojets constructed by Avro's sister company, Orenda Engines, Limited, Malton, Ontario.

The specification called for an all-weather heavily-armed interceptor capable of operation in extremes of climate, radar controlled, with a long range for patrolling Canada's wide areas. Such a specification implies a large aircraft, and the all-up weight of the CF100 is of the order of 37,000 lb. It was, therefore, surprising to see the CF100 indulging in spins and falling-leaf manoeuvres at Farnborough and spoke well for the pilot's confidence in the controllability of his aircraft. Excluding wing-tip fuel tanks or rocket pods, the wing span is 49 ft. 11 in. and the overall length is 54 ft. The tandem cockpit is pressurised for high altitudes and equipped with Martin Baker ejector seats, and the wing and tail surfaces are equipped with electrically operated de-icers.

The CF100 is in the high-subsonic speed class, and has exceeded the speed of sound in a dive—the first straight-wing aircraft to do so. It has a service ceiling of over 45,000 ft. and an operational range of more than 2,000 miles when fitted with tip tanks. On the Mark 4, the armament comprises 0·50 in. machine guns in the fuselage and rockets carried in a retractable fuselage pack and in wing-tip containers. The Hughes fire-control equipment searches out and locks on to the target, and automatically fires the selected weapons.

Structurally the CF100 is fairly conventional, of light-alloy flush-riveted construction, the wing structure comprising a three-web torsion box. Wing " finger-tip " dive brakes are provided and split landing flaps are fitted across the centre section and inner part of the outer wings. The flying controls are power-boosted by Fairey hydraulic actuators. A tricycle retractable undercarriage by Dowty is fitted, all units of which are twin-wheeled; the main wheels retract sideways into the centre section and the nose wheel backwards into the fuselage below the cockpit.

Next year, squadrons of R.C.A.F. CF100 fighters are likely to be seen in Europe, operating with NATO.

SWIFT FIGHTER-RECONNAISSANCE

Although the Mark 4 Swift has proved to be a disappointment as an interceptor, the possibilities of the design are not exhausted and this year a new version, the Swift F.R. Mark 5 tactical reconnaissance aircraft, was demonstrated at Farnborough by the Supermarine division of Vickers-Armstrongs Limited, Hursley Park, Winchester. Developed from earlier marks, the Swift Mark 5 is now in production for the Royal Air Force at the Supermarine works at Eastleigh, Itchen, and South Marston.

The Swift F.R. Mark 5, shown in Fig. 18, has a slightly larger fin than earlier versions, but is still powered by a Rolls-Royce Avon turbojet equipped for after-burning. It is fitted with three reconnaissance cameras and two Aden guns, and there is provision for a 220-gallon drop tank under the fuselage. The wing plan-form also differs from that of earlier Swifts, in that the area of the outboard part of the wing has been increased by extending the chord forward to give a " dog-tooth " effect; the purpose of this is to reduce the tendency for tip stalling and to increase the aileron effectiveness for manouevres at high altitude.

CANBERRA

Yet another version of the versatile Canberra aircraft, designed by the English Electric Company, Limited, Warton Aerodrome, Lancashire, was demonstrated for the first time at Farn-

Fig. 15 FD2 supersonic research aircraft. The Fairey Aviation Company, Limited.

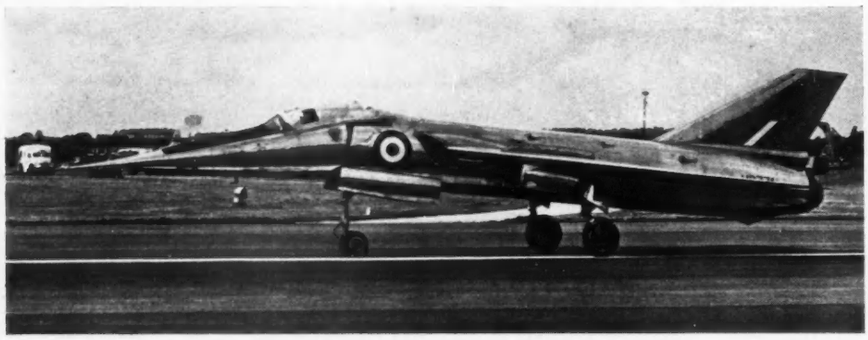


Fig. 16 FD2 with nose hinged for landing.

borough—the P.R. Mark 9 Canberra, designed for long-range photographic reconnaissance sorties at very high altitude. Canberra aircraft, it may be recalled, are also being constructed in the United Kingdom by Short Brothers and Harland Limited, A. V. Roe and Company, Limited, and Handley Page Limited; and under licence in America by the Glenn L. Martin Company, Baltimore, and in Australia by a Government factory near Melbourne. Fourteen international records have been set up by the Canberra, including the recent London-New York-London journey in less than 15 hours. The Canberra 9 has a larger wing than the P.R. Mark 7 from which it was developed, to enable it to operate over long ranges at higher altitudes well above the ceiling of present-day fighters. The wing between the fuselage and the engines has been extended chordwise, and the overall span is increased to 68 ft.—4 ft. more than the Mark 7. The Rolls-Royce Avon engines fitted also develop greater power.

The prototype P.R. Mark 9 shown at Farnborough has a standard Canberra nose with a large canopy, but the version now in production for the Royal Air Force will have an asymmetrical nose similar to that of the Canberra Mark 8 night intruder, which also appeared in the display. (This latter aircraft was illustrated on page 346 of the September 10, 1954, issue of ENGINEERING.) The pilot will be seated under a fighter-type canopy with the navigator in front and below him; this layout is particularly suitable for stowage of the equipment needed for accurate navigation.

This particular version of the Canberra is a product of co-operation between two companies of the English Electric Group—the basic design and wind tunnel work on the P.R. Mark 9 was carried out by the aircraft division of the parent company at Warton, and the detailing and construction of the first aircraft was completed by D. Napier and Son, Limited, at Luton airport, Bedfordshire.

THE V-BOMBERS

As already mentioned, the Valiant medium bomber, designed and constructed by Vickers-Armstrongs, Limited, Weybridge, Surrey, is now entering service in Bomber Command squadrons. The example demonstrated by its constructors in the flying display was a production B Mark 1 aircraft powered by four Rolls-Royce Avon turbojets and fitted with external long-range fuel tanks.

The Valiant has recently joined the Canberra in the long-distance speed campaign, and now claims international speed records for London to Baghdad (2,543 miles) at an average speed of over 523 m.p.h., and for Singapore to Darwin (2,080 miles) at an average speed of over 518 m.p.h. These two records, by a standard Valiant, were set up during the course of a flight from London to Darwin, Australia. On the London to Baghdad flight, the aircraft had to fly about 300 miles off course to avoid prohibited areas, and the ground speed achieved over the distance actually flown was over 586 m.p.h. On the Singapore to Darwin flight, the Valiant was flying against a 41 m.p.h. headwind.

The other V-bombers now in production, more recently designed than the Valiant, are still under development and there is no likelihood of their entering service before next year. Examples of both of these aircraft—the Sapphire-powered Victor, designed and constructed by Handley Page, Limited, Cricklewood, London, N.W.2, and the Olympus-powered Vulcan designed and constructed by A. V. Roe and Company, Limited, Greengate, Middleton, Manchester, appeared in the display, the latter providing one of the highlights by performing a roll—a remarkable sight on an aircraft of this size.

COASTAL AND NAVAL AIRCRAFT

The latest version of the Shackleton long-range reconnaissance aircraft designed and built by A. V. Roe and Company, Limited, the M.R.3, is in production for the Royal Air Force and has also been ordered for the South African Air Force. Like earlier Shacklетons, it is powered by four Rolls-Royce Griffin engines. It has a larger fuel capacity, and a new type of canopy giving better visibility. It is provided with a tricycle undercarriage to render landing easier for pilots fatigued by long hours of submarine searching. Another provision for minimising crew fatigue is the sound-proofed ward-room with seats, bunks and a galley for hot meals and drinks. In addition to carrying a large amount of radar gear and offensive weapons—the latter stowed in a capacious bomb bay—the Shackleton M.R.3 carries a lifeboat for air-sea rescue work.

Among the naval aircraft taking part in the flying display were a formation of four Sea Hawk light submarine-hunter aircraft, designed and constructed by Short Brothers and Harland Limited, Queen's Island, Belfast, now in production for R.A.F. Coastal Command and the Fleet Air Arm; one of the three twin-Avon-powered D.H. 110 fighter aircraft designed and constructed by the de Havilland Aircraft Company Limited, Hatfield, which are on order for the Fleet Air Arm and are currently undergoing flight tests to develop the aircraft to its full "navalised" condition, with external stores, folding wings, deck take-off and landing gear, radar, etc.; and two Fairey Gannets—one a trainer and the other a submarine hunter both now well established in service.

In the static park Sir W. G. Armstrong Whitworth (Aircraft) Limited, Coventry, displayed the latest tactical Sea Hawk—the Mark 4—now in production, with a load of bombs and rockets and equipped with drop tanks.

A subsequent article will deal with the static display at Farnborough.

* * *

STORAGE IN ALUMINIUM

Increasing use of combine harvesters on British farms means that more storage space is needed for the grain. Silos made from aluminium are very suitable for grain storage, since they can be erected quickly, can easily be moved, and aluminium excludes vermin, does not harbour pests and bacteria, and needs little maintenance. A battery of 36 100 ton silos were recently erected by Frederick Braby and Company Limited, Bristol, using Nord alloys made by the Northern Aluminium Company, Limited, Banbury, Oxfordshire.

The body of each silo is cylindrical, and is made in six rings, in the second of which is a 9 in. diameter outlet chute controlled by a gate valve. The roof is conical in shape, and is surmounted by a welded cone cap for waterproofing. Two of the roof panels are designed in overlapping halves. The lower half of each is removable for filling and emptying the silo, and the top edge of the silo is reinforced by special pressings at these points. The silo body is 15 ft. high (overall height, including the conical roof, 21 ft.) and 20 ft. in diameter. Its total weight is 12 cwt. and capacity 100 tons of wheat.

The shape of this silo, in which the diameter exceeds the height of the cylinder, is the outcome of experience; in earlier designs they were taller and of smaller diameter, the peculiar arch formations assumed by grain were found to give rise to an unduly high vertical thrust.

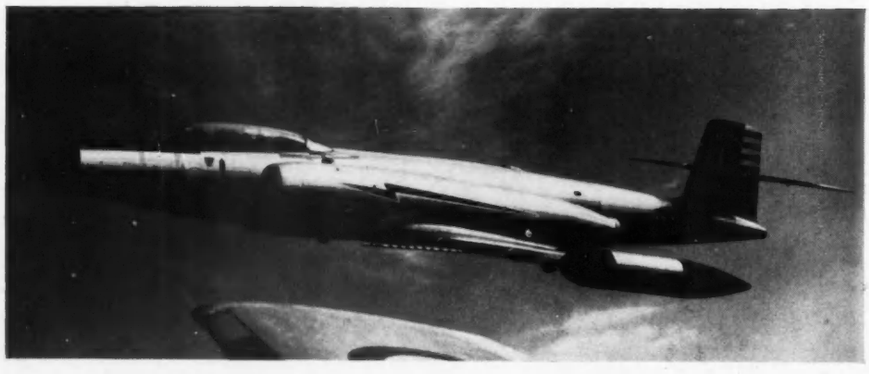


Fig. 17 CF100 all-weather fighter. Avro Aircraft Limited (Canada).

Fig. 18 Swift Mark 5 fighter reconnaissance aircraft. Vickers-Armstrongs Limited (Supermarine Division).

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

GLASGOW
"Motor Control Gear, with Special Reference to Machine-Tool Control," by R. F. Mathieson. Glasgow Branch. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. Wed., Sept. 28, 8 p.m.

British Institution of Radio Engineers

LONDON
"Extending the Limits of Resistance Measurement, Using Electronic Techniques," by G. I. Hitchcox. London Section. London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. Wed., Sept. 28, 6.30 p.m.
LIVERPOOL
"Stereophonic Sound," by R. A. Bull. Merseyside Section. Liverpool Chamber of Commerce, 1 Old Hall-street, Liverpool, 3. Wed., Oct. 5, 7 p.m.

Building Centre

LONDON
Films: "Bright New World"; and "Living with Formica" (Uses of "Formica" Plastics Sheeting). Wed., Sept. 28, 12.45 p.m.

Illuminating Engineering Society

LEEDS
Trotter-Paterson Memorial Lecture on "The Brightness of the Stars," by Sir Harold Spencer Jones. Leeds Centre. Chemistry Lecture Theatre, The University, Leeds. Mon., Sept. 26, 7 p.m.
LEICESTER
"Interesting Lighting Jobs." Various short papers. Leicester Centre. Offices of the East Midlands Electricity Board, Charles-street, Leicester. Mon., Sept. 26, 6 p.m.

Incorporated Plant Engineers

LONDON
"Air Pollution Problems and Their Cure," by J. B. M. Mason. London Branch. Royal Society of Arts, John Adam-street, Adelphi, W.C.2. Tues., Oct. 4, 7 p.m.
BIRMINGHAM
"The Do's and Don'ts of Refrigeration," by M. E. Lea. Birmingham Branch. Imperial Hotel, Birmingham. Fri., Sept. 30, 7.30 p.m.
CARDIFF
"Space Heating," by W. M. Barber. South Wales Branch. South Wales Engineers' Institute, Cardiff. Tues., Sept. 27, 7.15 p.m.
LEEDS
"Axial Flow Fans," by R. H. Holbeche. West and East Yorkshire Branch. Leeds University. Mon., Sept. 26, 7.30 p.m.
SHEFFIELD
"Steelmaking and the Plant Engineer," by R. Mayorcas. Sheffield and District Branch. Grand Hotel, Sheffield. Thurs., Sept. 29, 7.30 p.m.

Institute of Fuel

LONDON
"The Effect of Coal Quality on the Efficiency of a Shell Boiler Equipped with a Travelling-Grate Stoker," by E. J. MacDonald and M. V. Murray. Institution of Civil Engineers, Great George-street, S.W.1. Wed., Oct. 5, 5.30 p.m.

Institute of Marine Engineers and Institution of Naval Architects

PORTSMOUTH
"The History and Development of Submarines," by R. N. Newton. Southern Joint Branch. College of Technology, Anglesey-road, Portsmouth. Wed., Sept. 28, 7.30 p.m.

Institute of Road Transport Engineers

DURHAM
"Gas Turbine Development for Road Transport," by P. A. Phillips. North Eastern Centre. Three Tuns Hotel, Durham City. Tues., Sept. 27, 7 p.m.

Institute of Welding

LONDON
Presidential Address on "Recent Advances in Welding Processes and Plant," by Dr. J. H. Paterson. North London Branch. Manson House, 26 Portland-place, W.1. Thurs., Sept. 29, 7.30 p.m.

Institution of Electrical Engineers

LONDON
Presidential Address by Sir George H. Nelson. Thurs., Oct. 6, 5.30 p.m.
Chairman's Address on "Alternating-Current Switchgear," by M. H. F. Collins. London Graduates' and Students' Section. Mon., Oct. 10, 6.30 p.m.
BIRMINGHAM
Chairman's Address by Lieut.-Colonel H. S. Davidson. South Midland Centre. Annual General Meeting and Conversazione. Grand Hotel, Birmingham. Mon., Oct. 3, 6 p.m.
LEEDS
Chairman's Address by F. Barrell. North Midland Centre. Offices of the Yorkshire Electricity Division, 1 Whitehall-road, Leeds. Tues., Oct. 4, 6.30 p.m.
LIVERPOOL
Chairman's Address on "Electrical Discharges in Gases," by Professor J. M. Meek. Mersey and North Wales Centre. Liverpool Royal Institution, Colquitt-street, Liverpool. Mon., Oct. 3, 6.30 p.m.
MANCHESTER
Chairman's Address on "Ethical Aspects of the Electrical Engineering Profession," by G. V. Sadler. North Western Centre. Engineers' Club, Albert-square, Manchester. Tues., Oct. 4, 6.30 p.m.

Institution of Engineering Designers

LONDON
"Automatic Control," by P. J. Booker. London Branch. Wed., Sept. 28, 7 p.m.

Institution of Engineers and Shipbuilders in Scotland

GLASGOW
Presidential Address by Professor A. M. Robb. Tues., Oct. 4, 7.30 p.m.

Institution of Highway Engineers

LONDON
"Aerial Surveys and the Practical Application of Results Therefrom," by B. F. J. Bradbeer and others. Institution of Structural Engineers, 11 Upper Belgrave-street, S.W.1. Fri., Oct. 7, 5.30 p.m.

Institution of Locomotive Engineers

LONDON
"The British Railways Mechanical Iron Foundry, Horwich," by A. S. Smith. Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, S.W.1. Wed., Oct. 5, 5.30 p.m.

Institution of Mechanical Engineers

BARROW-IN-FURNESS
"Rapid-Starting Technique: Some Significant Tests at Poole Power Station," by J. S. Hall and A. F. Brittin. North Western Branch. Barrow Technical College, Abbey-road, Barrow-in-Furness. Fri., Sept. 30, 7.30 p.m.
LEICESTER
"Some Methods of Seamless Tube Manufacture," by D. E. John. East Midlands Graduates' Section. College of Technology and Commerce, The Newarke, Leicester. Mon., Sept. 26, 7.15 p.m.
NEWCASTLE-UPON-TYNE
"A Review of Freight Aircraft," by B. P. Laight. North Eastern Branch. Neville Hall, Westgate-road, Newcastle-upon-Tyne. Mon., Oct. 3, 6 p.m.

Institution of Production Engineers

BEDFORD
"Materials Handling," by K. B. Warwick and H. Dean. Luton Section. Queen's Works of W. H. Allen, Sons & Co., Ltd., Bedford. Tues., Sept. 27, 7.30 p.m.
CHELMSFORD
"Training of Production Managers and Production Engineers," by G. S. Bosworth. South Essex Section. Mid-Essex Technical College, Chelmsford. Wed., Oct. 5, 7.30 p.m.
LEEDS
"Valid Incentives," by E. C. Gordon England. Regional Meeting. Chemistry Lecture Theatre, The University, Leeds 2. Mon., Oct. 3, 7 p.m.
NOTTINGHAM
"Packaging," by E. H. Dickens. Nottingham Section. Victoria Station Hotel, Nottingham. Wed., Oct. 5, 7 p.m.
PETERBOROUGH
"A Lecture on Lecturing," by R. Parmenter. Peterborough Section. Campbell Hotel, Bridge-street, Peterborough. Tues., Oct. 4, 7.30 p.m.
READING
"Production Control as Applied to Small and Medium-Size Companies," by F. T. Hunter. Reading Section. Great Western Hotel, Reading. Thurs., Oct. 6, 7.30 p.m.

Institution of Works Managers

LONDON
Annual General Meeting and Film Evening. London Branch. Waldorf Hotel, Aldwych, W.C.2. Tues., Oct. 4, 7 p.m.
LEICESTER
Discussion on "Are Lawyers Useful to Business?" to be opened by Sir Geoffrey Barnett. Followed by Branch's Annual Dinner. Leicester Branch. Grand Hotel, Leicester. Tues., Oct. 4, 7 p.m.
MANCHESTER
"United Kingdom Exports and Foreign Competition," by S. G. Soman. Manchester Branch. Grand Hotel, Manchester. Mon., Oct. 10, 6.45 p.m.
NORTHAMPTON
Annual General Meeting. Northampton Branch. Franklins Gardens Hotel, Northampton. Tues., Sept. 27, 7.45 p.m.
SHEFFIELD
Discussion on "Productivity." Sheffield Branch. Grand Hotel, Sheffield. Tues., Oct. 4, 7.30 p.m.

Junior Institution of Engineers

LONDON
Film: "The Raising of H.M. Submarine Truculent," to be introduced by Lieut.-Commander L. Hackman, R.N.R. Fri., Oct. 7, 7 p.m.

Royal Aeronautical Society

LONDON
"The Growth of Aeronautical Research in Canada during the Post-War Decade," by Dr. J. J. Green. The Eleventh British Commonwealth and Empire Lecture. The Royal Institution, 21 Albemarle-street, London, W.1. Thurs., Oct. 6, 6 p.m.

Royal Statistical Society

LONDON
"Quality Control in the Paper Industry," by I. F. Hendry. London Industrial Applications Group. Lighting Service Bureau, 2 Savoy-hill, W.C.2. Fri., Oct. 7, 6 p.m.
SHEFFIELD
"Ultimate Capacity of a Slabbing Mill," by H. G. Jones. Sheffield Industrial Applications Group. Grand Hotel, Sheffield. Thurs., Sept. 29, 6.30 p.m.

Society of Chemical Industry

LONDON
"The Composition of Sprayed Aluminium Coatings," by F. A. Champion and G. W. Walkiden; and "Sprayed Alloy Coatings," by T. P. Hoar. Corrosion Group. Chemical Society's Apartments, Burlington House, Piccadilly, W.1. Wed., Oct. 12, 6.30 p.m.

Women's Engineering Society

LONDON
Discussion on "Refrigeration." London Section. Hope House, Great Peter-street, S.W.1. Wed., Sept. 28, 7 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 5927.)
British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1. (MUSeum 1901.)
Building Centre, 26 Store-street, London, W.C.1. (MUSeum 5400.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of Fuel, 18 Devonshire-street, Portland-place, London, W.1. (LANgham 7124.)
Institute of Marine Engineers, 85 The Minories, London, E.C.3. (ROYal 8493.)
Institute of Road Transport Engineers, 69 Victoria-street, London, S.W.1. (ABBey 6248.)
Institute of Welding, 2 Buckingham Palace-gardens, London, S.W.1. (SLOane 9851.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Engineering Designers, 38 Portland-place, London, W.1. (LANgham 8847.)
Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. (Central 5181.)
Institution of Highway Engineers, 47 Victoria-street, London, S.W.1. (ABBey 3891.)
Institution of Locomotive Engineers, 28 Victoria-street, London, S.W.1. (ABBey 6672.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Naval Architects, 10 Upper Belgrave-street, London, S.W.1. (SLOane 4622.)
Institution of Production Engineers, 10 Chesterfield-street, London, W.1. (GROsvenor 5254.)
Institution of Works Managers, 67-68 Chandos-place, London, W.C.2. (TEMple Bar 8324.)
Junior Institution of Engineers, Pepys House, 14 Rochester-row, London, S.W.1. (VICtoria 0786.)
Royal Aeronautical Society, 4 Hamilton-place, London, W.1. (GROsvenor 3515.)
Royal Statistical Society, 21 Bentinck-street, London, W.1. (WELbeck 7638.)
Society of Chemical Industry, 56 Victoria-street, London, S.W.1. (VICtoria 5215.)
Women's Engineering Society, 25 Foubert's-place, London, W.1.

LAUNCHES AND TRIAL TRIPS

M.S. "ATHELSTANE."—Single-screw tanker for the bulk carriage of molasses, oil, spirits or chemicals, built by Hawthorn Leslie (Shipbuilders), Ltd., Hebburn-on-Tyne, County Durham, for the Athel Line Ltd., London, W.1. Second of two sister ships. Main dimensions: 459 ft. overall by 61 ft. by 31 ft. to upper deck; deadweight capacity, about 10,000 tons. Hawthorn-Doxford four-cylinder combined-stroke opposed-piston oil engine, developing 4,450 b.h.p. at 112 r.p.m. in service, constructed by Hawthorn Leslie (Engineers) Ltd., Newcastle-upon-Tyne. Trial trip, August 30 and 31.

S.S. "SIR JOHN SNELL."—Single-screw self-trimming collier, built by Hall, Russell & Co., Ltd., Aberdeen, for the Central Electricity Authority, London, S.W.1. (Managers: Stephenson Clarke Ltd., London, E.C.3.) Main dimensions: 323 ft. between perpendiculars by 43 ft. 3 in. by 20 ft. 3 in.; deadweight capacity, about 3,700 tons on a draught of 18 ft. Triple-expansion steam engine of reheat design, developing 1,475 i.h.p. in service, constructed by the North Eastern Marine Engineering Co. (1938), Ltd., Sunderland. Steam generated by two oil-fired cylindrical boilers. Trial trip, September 6.

M.S. "GANNSFJORD."—Single-screw oil tanker, built and engined by the Götaverken Shipyard, Gothenburg, Sweden, for the joint ownership of Skips A/S Hidlefjord and Skibs A/S Byfjord, Stavanger, Norway. Main dimensions: 550 ft. overall by 60 ft. by 39 ft. 3 in.; deadweight capacity, about 17,360 tons on a draught of 30 ft. 2 in. Götaverken nine-cylinder single-acting two-stroke Diesel engine, developing 6,750 b.h.p. at 112 r.p.m. Service speed, about 15 knots. Delivered, September 6.

M.S. "FERNCOURT."—Single-screw oil tanker, built and engined by Eriksbergs Mek. Verkstads Aktiebolag, Gothenburg, Sweden, for Fearnley and Eger, Oslo, Norway. First of four vessels on order for these owners. Main dimensions: 570 ft. between perpendiculars by 77 ft. by 42 ft. 9 in.; deadweight capacity, 24,400 tons on a summer draught of 31 ft. 11 in.; oil-carrying capacity, 1,188,000 cub. ft. Eriksbergs-B. and W. eight-cylinder single-acting two-stroke Diesel engine, developing about 10,000 b.h.p., and arranged for burning heavy fuel oil. Service speed, 15¾ knots. Trial trip, September 7.

M.S. "FERNCLIFF."—Single-screw cargo vessel, with accommodation for twelve passengers, built and engined by Eriksbergs Mek. Verkstads Aktiebolag, Gothenburg, Sweden, for Fearnley and Eger, Oslo, Norway. Second of two sister ships. Main dimensions: 450 ft. between perpendiculars by 64 ft. by 41 ft. to shelter deck; total refrigerated-cargo capacity, about 25,000 cub. ft. There are also tanks for carrying 1,600 tons of vegetable oil and latex. Eriksbergs-B. and W. eight-cylinder single-acting two-stroke Diesel engine, developing about 10,000 b.h.p., and arranged for burning heavy fuel oil. Service speed, 15¾ knots. Launch, September 7.

M.S. "PRESIDENT KRUGER."—Single-screw cargo vessel, built by the Furness Shipbuilding Co., Ltd., Haverton Hill, County Durham, for the Northern Steamships Ltd., Johannesburg. Second vessel constructed for these owners. Main dimensions: 435 ft. 8 in. between perpendiculars by 59 ft. by 39 ft. 2 in. to upper deck; deadweight capacity, 11,165 tons on a summer draught of about 27 ft. 10 in.; total capacity, 614,021 cub. ft. Hawthorn-Doxford four-cylinder single-acting two-stroke opposed-piston oil engine, developing 4,400 b.h.p. at 115 r.p.m., constructed by Hawthorn Leslie (Engineers), Ltd., Newcastle-upon-Tyne. Trial trip, September 12.

THE HUMAN ELEMENT

Britain relatively free from strikes: in Northern Rhodesia the African has a new chance to advance; in the United Kingdom the inquiry into coal production is being pressed forward; an unsatisfactory piecework system changed to a merit system; gradual shift to three-shift working in Lancashire textiles; and in Scotland the old towns are suspicious of the new towns.

* * *

Strikes Here and Abroad

Which countries have had the heaviest incidence of strikes in the last few years and what are the reasons for it? A recent analysis in the *International Labour Review* gives the answer to the first part of this question and thereby sheds some light on the second. The picture is hardly what most people would expect.

The basis used for the comparison is the number of days lost per thousand employed, and allowing for some slight differences in the way in which the figures are prepared the general outline, based on the average for the years 1947 to 1954, looks like this. In the top group, that is those with only up to, say, 200 days lost per thousand employees in the average year, Switzerland leads easily with 39, followed by the Netherlands, Scandinavia, West Germany and the United Kingdom last with 151. Then there is a big gap with Canada next at 736. Between that and 1,000 are such countries as Belgium, Japan and Australia. In the lowest group, between 1,000 and 2,000, are Italy, France, the United States and Finland—in that order. It has to be said in fairness to the last group that their figures have become progressively and rapidly smaller in the last two years.

Interpretation of these figures is not easy, for the groups are very mixed. At the top are countries with strongly organised trade unions (as in Scandinavia and the United Kingdom) and a central trade union secretariat. In the case of the Netherlands wage movements are nationally controlled. In the middle group there are countries with a tradition of trade union militancy like Australia. At the bottom are those which suffer from political agitation and weak central trade union organisation but have strong trade union bargaining power and militancy. A tentative conclusion might be that the figures are apt to be highest where there is political agitation, little trade union organisation at the national level but a strong bargaining position. Any one or any combination of these may reduce industrial peace. One important point comes out of these figures, namely, that industrial unrest the world over causes a smaller loss of time than illness and absenteeism.

* * *

African Advancement

An important step forward in the maintenance of industrial peace in the Northern Rhodesian copper belt has been achieved. The Rhodesian Selection Trust group of companies and the Northern Rhodesia European Mineworkers Union have announced that they have reached agreement on African advancement. The white union has agreed to make reasonable concessions to aid in the promotion and training of Africans. Job analysis is to start right away and the union is presumably agreeable to discussing the promotion of African labour to such jobs as this independent valuation finds to be suitable. The question of promoting Africans to skilled jobs which are at present on a reserved list for Europeans is to be opened in three years' time.

It now remains for the African union to endorse the settlement if the new spirit of conciliation is to be effective. If this endorsement is forthcoming, an important step has been achieved in resolving the problem of the colour bar in the Northern Rhodesian copper industry. It is a triumph for moderation, in which quiet counsels behind the scenes from the trade union movement in this country have played a part. The value of having a mature attitude in black and white management-labour relations in Africa at the present time could hardly be over-emphasised. The copper belt might now provide it.

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Early Start to Coal Inquiry

The National Coal Board and the National Union of Mineworkers are to begin their joint investigation into manpower and production before the end of this month. Procedure was agreed at a meeting held at the end of last week. It looks as though a compromise has been found between the need to make a quick probe and the desirability of getting as close to the problems of the individual pits as possible. On balance, speed seems to have carried the day against thoroughness. This, in turn, has no doubt been decided for reasons of expediency—to strike while the iron is hot. The iron in this case is the evident willingness of the union leaders to make a co-operative gesture since the union has rejected foreign labour. If this willingness has really percolated down to the local union representatives and active union members, the compromise will have been the right one. If not, thoroughness would be a better aim than speed.

Meetings are to be held at focal points in the coalfields to which representatives from local collieries can come, and if time permits the members will visit individual collieries. The committee consists of Sir Hubert Houldsworth, the board's chairman, Mr. J. Bowman, vice-chairman, Mr. W. H. Sales, the board member responsible for industrial relations, Mr. Ernest Jones, president of the union, Mr. Ted Jones, the vice-president, and Mr. Arthur Horner the general secretary.

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Merit System v. Piecework

" An Alternative to Piecework " was one of the papers given this week at the 6th Residential Summer School held by the Institute of Cost and Works Accountant at Oxford. This lecture, given by Mr. Ivor B. Cooke, was a case study from his own company's experience in South Wales. It is of interest not only as a practical example of how an unsatisfactory piecework system was changed but also of how the introduction of another system in one part of the works gradually spread elsewhere and built up good management relations as it went along. The concern is in electrical engineering.

The company decided that the time had come to improve the calibre of certain unskilled grades by raising the quality of the intake. A simple merit rating scheme was adopted and worked satisfactorily. In due course, however, difficulty arose in one of the shops where a bonus was paid to skilled fitters whose work could not be assessed on a piecework basis and where a bonus was paid instead. Meanwhile, the machinists in the shop were on piecework. Fitters' and machinists' wages had got out of step. It was decided to instal a merit rating system on the lines which had been worked out for the indirect and unskilled workers some time before. A merit system was devised with care and the full co-operation obtained from all levels of supervision, from the shop stewards and from the men themselves. At the end of three months the scheme went into the fitting shop. Three months later the pattern shop went on to a similar one and 12 months later the machine shop followed. One of the things thrown up by this systematic examination of merit among the men was the uneven quality of the supervision, and in due course the foremen went on a merit basis as well. A point of interest in this gradual progression was that when a man complained, he was given the opportunity to rate himself—and usually gave himself a lower rating than he got under the scheme.

Output and workmanship improved under the merit system, which is still in operation, and industrial relations have been successfully built up, the discussion of merit rating having stimulated a vigorous form of joint consultation.

* * *

Shift Working in Cotton

Some progress has been made in the move to introduce triple-shift working into the Lancashire cotton textile industry which was commented upon in these notes three weeks ago. The issue was discussed last week by leaders of the seven unions in the weaving section. According to a statement afterwards by the secretary of the Northern Counties Textile Trades Federation, Mr. Lewis Wright, certain recommendations will be discussed (probably this week) with the spinning unions. All that Mr. Wright would say was that the weaving unions had not rejected the proposal for triple-shift working. It is not likely that anything more hopeful for Lancashire than this will be heard until the spinning and weaving unions have held their discussions, for clearly a break with tradition of this magnitude calls for a common front in the eyes of the trade union world. At the moment it can at least be said that the weaving unions are not categorically against the change.

A touch of spice and urgency has been given to the discussions by two developments. First, there is every indication that the drain of labour from cotton textiles is going on. The latest figures of employment in the industry show that the drift away has scarcely slacked in the last few weeks. In addition, a certain Lancashire company has let it be known that it will proceed with a £500,000 modernisation programme only if it can be sure that the new equipment will run on a three-shift basis. Facts such as these indicate the urgency of the matter. It will require the greatest expedition by all parties to deal with this lively issue, for even at best the process of discussion between both sides of industry in cotton textiles is complicated by the multiplicity of organised groups who have to be consulted and who have to think in terms of adjusting not only a single shift, but also a double-shift system on to a three-shift basis.

* * *

Scottish Old Towns and New Towns

Last week, when the Scottish section of the Town and Country Planning Association met at Oban, it was addressed by the Scottish secretary of the Federation of British Industries on the dangers of moving industry in too wholesale a fashion from large industrial centres. The same week saw views expressed on the same subject by the Scottish Trades Union Congress in the form of an announcement about the agenda for a series of forthcoming meetings, and by Scottish members of the National Union of Mineworkers in Lanarkshire.

The Scottish T.U.C. proposes to hold three conferences shortly—one on Highland development, one on north-east coast unemployment and one on Lanarkshire unemployment. They are concerned about the amount of new industry going into the Midlands and the south of England, but particularly in the case of Lanarkshire they are bound to take into account the movement of industry within Scotland from West to East. This fits in with the recent activities of a Lanarkshire branch of the N.U.M. which has submitted a plan to the Scottish area of the N.U.M. in Edinburgh to help ease " the economic plight of the county." It includes the use of untenanted factories by direct Government utilisation if necessary. The scheme is being examined in Edinburgh this week by a special conference of representatives from the Scottish coalfields.